DECEMBER 1979

SWINE RESEARCH REPORTS

Agricultural Experiment Station
Cooperative Extension Service
College of Agriculture
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

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Contents

1979-1 Response of Young Pigs to Environmental Stress and Dietary Antibiotics
A.H. Jensen

1979-2 Dietary Crude Protein Level Sequences for Growing-Finishing Pigs
A.H. Jensen and Tom Park

1979-3 Response of Growing Pigs to Various Dietary Antibiotics
K.L. Adams and A.H. Jensen

1979-4 Oxidation Ditch Mixed Liquor as a Source of Certain Nutrients for Finishing Swine
A.H. Jensen, G.R. Frank and D.L. Day

1979-5 Effects of Management and Environment Modification on Performance of Finishing Swine
A.H. Jensen

1979-6 Estrus and Conception in Lactating Sows and Piglet Performance as Influenced by Limited Nursing
L.H. Thompson and A.H. Jensen

1979-7 Blood Groups in Swine
B.A. Rasmusen

1979-8 Effects of Protein Level, Physical Form, and Content of Regular and Opaque-2 Corn on Utilization of Simple and Complex Diets by Weaned Four-Week-Old Pigs
K.L. Adams and A.H. Jensen

1979-9 Every-Third-Day Feeding of Gestating Gilts and Sows
R.A. Easter, D.H. Baker, E.J. Michel and J.K. Rundquist

1979-10 Calcium Chloride as a Feed Intake Regulator for Self-Fed Gilts During Gestation
G.W. Willis and D.H. Baker

1979-11 Efficacy of Several Antibiotics for Growth Promotion
R.A. Easter, G.R. Hollis, J.A. Cuaron and H. Cook

1979-12 Performance of Pigs on Low-Quality Waters
M.D. Shoopman and S.E. Curtis

Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. JOHN B. CLAAR, Director, Cooperative Extension Service, University of Illinois at Urbana-Champaign. The Illinois Cooperative Extension Service provides equal opportunities in programs and employment.

University of Illinois at Urbana-Champaign

College of Agriculture — Agricultural Experiment Station
Cooperative Extension Service — Department of Animal Science

December, 1979

Response of Young Pigs to Environmental Stress and Dietary Antibiotics

A.H. JENSEN

Wilson *et al.* (1977) reported that in an environmentally controlled chamber with 35°C (95°F) ambient temperature, 4-week-old pigs on aluminum slat flooring gained more slowly and less efficiently than pigs on floors of either expanded metal, wood slats, or concrete slats. Reducing the temperature to 22°C (72°F) increased the differences. In a subsequent study (Hathorn *et al.* 1979) flooring material—plastisol coated steel mesh, aluminum slats, concrete slats and galvanized woven steel wire—had no significant effect on performance of pigs in either 35°C (95°F), 27°C (81°F), or 18°C (65°F) environments.

EXPERIMENTAL PLAN

The present study was a comparison of performance of weaned 4-week-old pigs in pens, within the same building, having either regular steel or stainless steel floors and solid (plywood) or wire-gate partitions. The steel slats were 7.5 cm. (3 inches) wide and spaced 1.9 cm. (3/4 inch). The stainless steel sections were acquired from Behlen Mfg. Co., Columbus, Nebraska. The partitions were 75 cm. (30 inches) high. Pen size was 0.9 meter (3 feet) by 2.7 meters (9 feet) and the building was mechanically ventilated.

The pigs were placed on test when they were weaned, and averaged about 6.8 kg. in weight. Feed and water were available at all times. The 18 percent crude protein diet had either 0 or 55 ppm of Mecadox.

The experimental plan designated a room temperature schedule as follows: day 1 through 3, 26°C (80°F); day 4 through 14, 24°C (75°F); day 15 through 26, 21°C (70°F). A hygrothermograph on the floor was used to continuously record ambient temperature and humidity. Incidence and severity of scours were also recorded.

RESULTS

Forty-eight hours after start of the trial, electrical power was lost due to a storm, and power was off for 72 hours. Average floor level temperaure during this period was 10°C (50°F), ranging from 6°C (43°F) for the first 20 hours of the power loss to 18°C (65°F) the last few hours before power was restored. Considerable huddling and piling-on occurred in each pen, with obvious shivering.

The results for the first 7 days, which encompassed the power-failure period, and the total 26-day period are shown in Tables 1 and 2.

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Table 1. Summary of Results of Pigs on Either Stainless Steel or Steel Slats in Pens with Wire-gate or Solid Partitions.

	Partition		
	Open	Solid	Avg.
Average initial wt., kg[a]			
Stainless steel	6.6	6.9	6.8
Steel	6.8	6.7	6.7
Avg.	6.7	6.8	
Average daily gain, kg.			
First 7 days			
Stainless steel	.12	.19	.15
Steel	.12	.12	.12
Avg.	.12	.15	
Total 26 days			
Stainless steel	.30	.36	.33
Steel	.31	.32	.31
Avg.	.30	.34	
Average daily feed, kg.			
First 7 days			
Stainless steel	.25	.29	.27[b]
Steel	.24	.25	.24
Avg.	.24	.27	
Total 26 days			
Stainless steel	.57	.68	.62
Steel	.60	.61	.60
Avg.	.58	.64	
Gain/feed			
First 7 days			
Stainless steel	.470	.641	.555
Steel	.508	.450	.479
Avg.	.489	.545	
Total 26 days			
Stainless steel	.533	.537	.535
Steel	.522	.527	.524
Avg.	.527	.532	

[a]Each value is an average for 4 pens of 8 pigs each.

[b]Pigs on stainless steel floor on the average consumed significantly more ($P<.05$) feed than those on steel slats.

Table 2. Response of Pigs in Pens of Different Floor and Partition Materials to Dietary Mecadox.

	Level of Mecadox, ppm[a]	
	0	55
Average daily gain, kg.		
First 7 days	.10	.17[b]
Total 26 days	.28	.37[b]
Average daily feed, kg.		
First 7 days	.23	.28[b]
Total 26 days	.56	.67[b]
Gain/feed		
First 7 days	.427	.608[c]
Total 26 days	.505	.555[b]

[a]Level of active ingredient.
[b]Effect of dietary Mecadox significant ($P<.01$).
[c]Effect of dietary Mecadox significant ($P<.05$).

SUMMARY

On the average, gains, feed consumption, and gain/feed values were slightly higher for pigs in pens with solid partitions than for those in pens with wire-gate partitions. Pigs on stainless steel floors performed slightly better than those on steel slat floors. During the first 7 days, pigs on stainless steel consumed significantly ($P<.05$) more feed than pigs on steel slats.

Pigs receiving dietary Mecadox performed at a significantly higher level than pigs with no Mecadox.

Incidence and severity of scours were minimal, with no apparent trends within the various comparisons.

There were no significant interactions between diet and pen environments.

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December, 1979

Dietary Crude Protein Level Sequences for Growing-Finishing Pigs

A.H. JENSEN AND TOM PARK

The most recent National Research Council publication (NRC, 1979) suggests that growing-finishing pigs weighing 20-35 kg. require 16 percent crude protein in their diets; pigs weighing 35-60 kg., 14 percent; and those weighing 60-100 kg., 13 percent. For several years the University of Illinois recommendations have been 16 percent for pigs from 15 to 55 kg., 14 percent for those from 55 to 100 kg. The NRC requirements represent an attempt to identify precisely the changes that occur in protein requirements with increase in pig size. The U. of I. recommendations represent a judgmental evaluation of nutritional adequacy with minimal number of different diets from weaning to market weight.

We thus conducted an experiment to compare performance of growing-finishing pigs fed either the NRC or the U. of I. crude protein sequence.

One hundred twenty-eight crossbred pigs averaging about 15 kg. were used. From outcome groups of four based on ancestry, weight, and sex, pigs within sex were randomly allotted to treatment.

	Size of pigs		
Sex	15 to 35 kg. (33 to 77 lb.)	35 to 60 kg. (77 to 132 lb.)	60 to 100 kg. (132 to 220 lb.)
		Dietary protein, pct.	
Males	16	14	13
Males	16	16	14
Females	16	14	13
Females	16	16	14

The dietary formulas are shown in Table 1.

From start to 35 kg. the pigs were confined to stainless steel slotted floor pens; from 35 to 100 kg. they were confined to pens on slats 12.5 cm. (5 inches) wide spaced at 2.5 cm. (1 inch). Feed and water were available at all times.

RESULTS

The data in Table 2 show that similar gains and feed intakes were realized with both feeding regimens. Feed efficiency was improved during the 35 to 60 kg. and 60 to 100 kg. periods with the 1 percent additional dietary crude protein.

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If we assume a price of $2.50 per bushel for corn and $180.00 per ton for soybean meal, feed cost per pig from 15 to 100 kg. was about $1.50 higher for the 16-14-13 percent than for the 16-14 percent dietary crude protein levels. There were no significant differences between males and females in the performance criteria measured.

Table 1. Diet Formulations

Ingredients	Dietary crude protein, pct.[a] 16	14	13
Ground yellow corn (8.8%)	78.45	84.45	86.45
Soybean meal (48.5%)	19.00	13.00	11.00
Dicalcium phosphate	1.25	1.25	1.25
Ground limestone	0.75	0.75	0.75
Trace mineralized salt	0.35	0.35	0.35
Illini vitamin mix	0.10	0.10	0.10
Pro-step	0.10	0.10	0.10
	100.00	100.00	100.00
Calculated, pct.			
Crude protein	16.0	14.0	13.0
Lysine	.74	.60	.53
Calcium	.60	.60	.60
Phosphorus	.54	.52	.51

[a]Crude protein levels obtained by adjusting respective quantities of corn and soybean meal.

SUMMARY

With fortified corn:soybean diets, a feeding regimen of dietary crude protein levels of 16 percent from 15 to 35 kg., 14 percent from 35 to 60 kg., and 13 percent from 60 to 100 kg. showed no advantage over a regimen of 16 percent from 15 to 60 kg. and 14 percent from 60 to 100 kg. for growing-finishing pigs.

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Table 2. Summary of Results of Growing-Finishing Pigs Fed Different Dietary Crude Protein Level Sequence

	Dietary crude protein, pct.		
Start to 35 kg.	16	16	
35 to 60 kg.	14	16	
60 to 100 kg.	13	14	Avg.
Average initial wt., kg.[a]	15.5	15.0	15.2
Average daily gain, kg.			
Start to 35 kg.	.46	.43	.45
35 to 60 kg.	.62	.63	.62
60 to 100 kg.	.78	.79	.78
Start to 100 kg.	.61	.61	.61
Average daily feed, kg.			
Start to 35 kg.	1.02	0.94	0.98
35 to 60 kg.	2.24	2.06	2.15
60 to 100 kg.	3.30	3.16	3.23
Start to 100 kg.	1.85	1.75	1.80
Gain/feed			
Start to 35 kg.	.451	.457	.459
35 to 60 kg.	.277	.306	.291
60 to 100 kg.[b]	.236	.255	.245
Start to 100 kg.[b]	.331	.348	.339

[a]Each value is an average for 8 pens of 8 pigs each (4 pens of males and 4 pens of females).
[b]Differences in gain/feed significant (P<.05).

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December, 1979

Response of Growing Pigs to Various Dietary Antibiotics

K. L. ADAMS AND A. H. JENSEN

The beneficial effects of certain dietary antimicrobials on growth rate and feed utilization in swine have been extensively documented *(1-6)*.* Even though these dietary growth promotants have been used in swine diets for more than a quarter of a century, the specific reason why they do what they do is not known. Early studies indicated that the positive responses resulted from metabolic *(7)*, nutrient-sparing *(8)*, or disease-control *(9)* effects, singly or in combination. Various extensive investigations within these broad categories have subsequently been conducted and are covered in such excellent reviews as those of Wallace *(10)* and Visek *(11)*.

Yen *et al.* *(12)* reported that the addition of 55 ppm of Carbadox to a corn: soybean meal diet significantly increased growth rate and feed efficiency of growing pigs, and that low (sub-therapeutic) levels of several other dietary additives have frequently resulted in faster and more efficient gains by clinically healthy pigs. With the continuing controversy about the use of antibiotics in livestock feed, it seemed desirable to evaluate the current response to dietary antibiotics of pigs from weaning to 34 kg. (75 lb.) in weight and subsequent performance to 57 kg. (125 lb.).

EXPERIMENTAL PROCEDURE

Two hundred ten pigs weaned at 4 weeks of age were used in two experiments. They were formed into outcome groups on the bases of ancestry, sex, and weight. Individual pigs were then randomly assigned to treatment. For the first 42 days, pigs were confined to cleaned and disinfected nursery pens, 1 meter x 3 meters, with stainless steel floors. They were then moved to a clean, partially slotted floor unit with pens 2 meters x 4 meters. In the nursery the temperature, by means of thermostatically controlled space heaters, was maintained at 27°C (80°F) for the first 7 days, 24°C (75°F) for days 8 through 14 and then 21°C (70°F) from day 15 through 42.

A 20 percent crude protein diet (Table 1) was fed the first 28 days; a 16 percent crude protein diet, from day 28 until the pigs averaged about 57 kg. (125 lb.) in weight. The dietary antibiotics were removed from the diet after the pigs

*Italicized numbers in parentheses refer to the "Literature Cited" on page 3.

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reached 34 kg. 75 lb.). Water was available from a nipple waterer in each pen. Pigs were weighed on days 1, 7, 14, and 21, at approximately 34 kg. (75 lb.); and at 57 kg. (125 lb.).

Table 1. Control Diets Used for the First 28 Days and From Day 29 Until Pigs Averaged About 57 kg.

Ingredient	First 28 days	29 days to 57 kg.
	Pct.	Pct.
Yellow corn	51.95	78.55
Soybean meal[a]	22.00	19.00
Rolled oats	20.00	-
Fish meal	3.00	-
Dicalcium phosphate	1.50	1.25
Ground limestone	1.00	0.75
Trace mineralized salt	0.35	0.35
Vitamin mix	0.20	0.10
	100.00	100.00
Calculated, pct.		
Crude protein	20.00	16.00
Lysine	1.00	0.74
Calcium	0.96	0.60
Phosphorus	0.70	0.54

[a]Assumed to contain 48.5 percent crude protein and 3.0 percent lysine

Dietary treatments to 34 kg. (75 lb.) were:

			Active ingredient, ppm of diet
1.	Control[a]		
2.	Control plus	.25% ASP-250[b]	110 ~~550~~A, 110 ~~550~~S, 55 ~~275~~P
3.	Control plus	.25% CSP-250[c]	110 ~~550~~C, 110 ~~550~~S, 55 ~~275~~P
4.	Control plus	.25% Mecadox	55
5.	Control plus	.20% Tylan	44
6.	Control plus	.10% Virginiamycin	22
7.	Control plus	.20% Aureomycin	44

[a]The control diet was fed to all pigs from 34 kg. (75 lb.) to 57 kg. (125 lb.).
[b]Aureomycin, sulfamethozine, and penicillin.
[c]Chlortetracycline, sulfathiazole, and pencillin.

RESULTS

The data in Table 2 show that each dietary antibiotic stimulated growth rate (P<01) and feed intake (P<.01) up to 34 kg. (75 lb.). Between 34 kg. and 57 kg. differences among groups were not significant. For the total period from start to 57 kg., however, gain and feed intake by the groups that had received antibiotic up to 34 kg. were greater (P<.05) than those by the pigs that had received no antibiotic throughout. Feed efficiency was not significantly affected.

SUMMARY

Results of these trials show that dietary antimicrobials at sub-therapeutic levels stimulated growth rate and feed intake in pigs from 7 to 34 kg.

From 34 to 57 kg., with all antimicrobials removed from the diets, pigs previously given the antimicrobials had gains and feed intake that were not significantly higher than those of the control pigs.

Table 2. Response of Growing Pigs to Various Dietary Antibiotics

Feed additive	Control	ASP-250	CSP-250	Mecadox	Tylan	Virgina-mycin	Aureo-mycin
Avg. initial wt., kg.[a]	7.2	7.3	7.3	7.3	7.3	7.2	7.1
Avg. daily gain, kg.							
Start to 34 kg.	.33[b]	.52	.51	.52	.44	.47	.46
34 to 57 kg.[c]	.73	.80	.77	.76	.74	.76	.79
Start to 57 kg.	.48[b]	.62	.61	.61	.55	.58	.58
Avg. daily feed, kg.							
Start to 34 kg.	0.74[b]	1.00	0.96	1.02	0.89	0.92	0.93
34 to 57 kg.	1.83	1.96	1.94	1.97	1.96	1.95	2.16
Start to 57 kg.	1.08[d]	1.35	1.33	1.37	1.29	1.30	1.38
Gain/feed							
Start to 34 kg.	.48	.52	.54	.51	.50	.51	.50
34 to 57 kg.	.41	.41	.41	.39	.38	.39	.37
Start to 57 kg.	.~~47~~ 44	.46	.46	.45	.42	.44	.42

[a]Each value is an average for 30 pigs, 2 pens of 6 pigs each in 2 replicates and 2 pens of 9 pigs each in 2 replicates.
[b]Control pigs less (P<.01) than pigs receiving antibiotics.
[c]Antibiotics not included in any diet during this period.
[d]Control pigs less (P<.05) than pigs receiving antibiotics.

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December, 1979

Oxidation Ditch Mixed Liquor as a Source of Certain Nutrients for Finishing Swine

A.H. JENSEN, G.R. FRANK AND D.L. DAY

Considerable research on processing and using poultry and ruminant wastes as dietary ingredients for ruminants has been reported (Fontenot and Webb, 1974; Anthony, 1974; Smith and Wheeler, 1979). Also, the use of fresh swine feces as a potential ingredient in ruminant diets has been investigated (Hilliard *et al.*, 1979; Ngian and Pearce, 1979). But relatively little information on the use of swine waste as a nutrient source for swine is available. Diggs *et al.* (1965) reported that swine waste scraped from a concrete feeding floor could, after being dried, be included in a diet up to a level of 15 percent without depresseing performance of finishing pigs. Kornegay *et al.* (1977) showed that fresh or dried feces from finishing pigs could make up as much as 37 percent of diet dry matter before consumption was significantly reduced. In 125-kg. gilts, digestibility of all proximate components decreased significantly as level of feces increased. Orr *et al.* (1973), Harmon *et al.* (1971 and 1973) and Harmon (1976) reported that storing swine wastes in oxidation ditches offered potential for the biological upgrading of the wastes as nutrient sources.

Harmon and Day (1975) fed oxidation ditch mixed liquor (ODML) as the sole source of drinking water and as a source of bacterial protein. When finishing pigs were *ad libitum* fed a fortified corn-soybean meal ration with 12 percent crude protein, pigs receiving ODML gained faster and more efficiently than those receiving tap water.

The present report summarizes the results from trials conducted to further evaluate ODML as a source of supplemental protein, B-vitamins (riboflavin, niacin, pantothenic acid, choline and B_{12}), and minerals (calcium and phosphorus).

EXPERIMENTAL PROCEDURES

Four trials involving 560 pigs were conducted. The pigs were confined to 1.8- by 3.5-meter pens in an enclosed building with a partially slotted concrete floor. During the winter the ambient temperature was maintained at a minimum of 15°C by use of a thermostatically controlled gas-fired space heater. Allotment of pigs to treatment was made from outcome groups based on ancestry, weight, and sex. The diets were fed *ad libitum*. All pigs were treated with an anthelmintic 72 hours before their assignment to the building.

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Figure 1 shows the system for recycling. The sump pump was operated on a time-clock series of 5 minutes on, 5 minutes off. Each trough served 2 pens of pigs. A small opening in the bottom of each trough ensured draining of unconsumed oxidation ditch mixed liguor (ODML) back to the ditch. This prevented accumulation in the trough of ODML that could rapidly become anaerobic. For a 3-hour period, once every 7 days, the ODML was shunted through a screen-type liquid-solid separator to remove hair and other solids that are resistant to bacterial breakdown and could in time interfere with efficient pump action. Flow rate to the screen was about 19 liters per minute, and about 570 liters of wet solids were removed each screening period. The liquid was returned to the ditch and additional tap water was added to ensure that the ditch material would be maintained at the proper depth.

Pigs on the ODML treatment had no other water. Tap water was provided by nipple waterers to pigs not receiving ODML. Samples of ODML were taken weekly by immersing a 50-cc plastic open-top bottle to a depth of 15 cm. Nitrates, total solids, chemical oxygen demand (COD), temperature, and pH determinations were made. At the end of each trial, representative animals were slaughtered and examined for evidence of ascarid infestation.

The summary results are shown in Tables 1-4. Typical analyses of the ODML are shown in Tables 5 and 6.

RESULTS

In trial I, pigs fed the diet supplemented with B-vitamins and Ca-P and receiving tap water gained significantly faster and consumed significantly more feed than the pigs fed the unsupplemented diets and receiving ODML. Pigs fed the 16-14 percent dietary protein sequence gained significantly faster than the pigs fed the 14-12 percent sequence. Gain/feed, however, was not affected by treatment and there were no interactions among dietary nutrient levels and drinking water source.

In trial II, a 2 x 2 x 2 factorial, gain and gain/feed of finishing pigs were significantly affected by dietary protein level (14 vs 12 percent) but not by supplemental B-vitamins or by source of drinking water.

In trials III and IV, neither the level of B-vitamins nor the level of Ca-P affected performance of finishing pigs. However, humerus bone mass per unit of live bodyweight was significantly ($P<.10$, trial III; $P<.005$), trial IV) reduced when the diet contained no supplemental Ca-P. In trial IV rate of gain ($P<.01$), feed intake ($P<.01$) and gain/feed were lower when ODML was the source of water. This appeared to reflect the higher ODML nitrate levels that persisted during this trial.

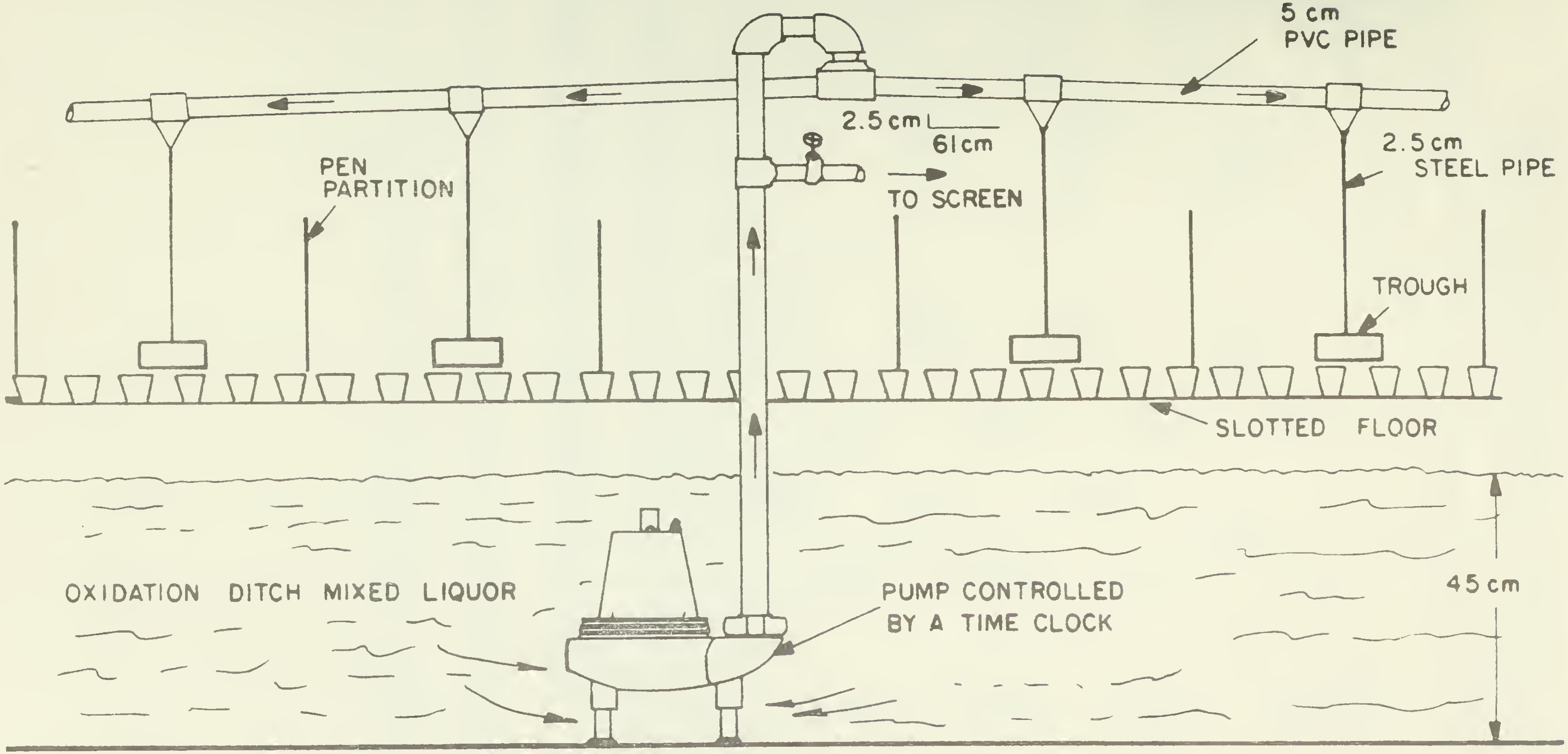

Figure 1. Schematic drawing of physical arrangement for sutomated cycling of ODML as a source of water. (Enclosed building, partially slotted floor.)

Table 1. Effects of Source of Drinking Water, Dietary Protein Level, and Dietary Supplemental Vitamins, Calcium, and Phosphorus on Performance of Growing-Finishing pigs (Trial I)

ODML	–[a]	+	+	
Vitamins added[b]	+	–	+	
Calcium and phosphorus added[c]	+	+	–	
Average initial weight, kg.[d]				Average
16% C.P. diet[e]	28.2	29.0	28.4	28.5
14% C.P. diet[e]	28.5	28.9	29.0	28.8
Average	28.3	28.9	28.7	
Average daily gain, kg.				
16% C.P. diet	.81	.71	.73	.75
14% C.P. diet	.76	.68	.69	.71
Average[f]	.78[†]	.69[‡]	.71[‡]	
Average daily feed, kg.				
16% C.P. diet	2.40	2.10	2.14	2.21
14% C.P. diet	2.38	2.08	2.18	2.21
Average[f]	2.39[†]	2.09[‡]	2.16[‡]	
Gain/feed				
16% C.P. diet	.338	.339	.343	.340[g]
14% C.P. diet	.322	.327	.318	.322
Average	.330	.333	.330	

[a]Received tap water as source of drinking water.
[b]Riboflavin, niacin, pantothenic acid, choline and B_{12} were either not added, or added to the dry diet to ensure dietary levels at least equal to the NRC (1973) suggested dietary requirements.
[c]Supplemental levels were either none or sufficient to ensure dietary levels of calcium and phosphorus at least equal to NRC (1973) suggested dietary requirements.
[d]Each value is an average for two pens of eight pigs each. Trial lasted 78 days.
[e]Protein levels were reduced 2 percentage points when the pigs reached an average of 50 kg. in weight.
[f]Treatment means with different superscripts are different ($P<.05$).
[g]Values from higher dietary protein greater ($P<.05$) than from lower protein levels.

Table 2. Response of Finishing Pigs to Source of Drinking Water and Dietary Levels of Protein and Supplemental Vitamins (Trial II)

Dietary protein, pct.[a]	14		12		
Vitamin level[b]	1	.5	1	.5	
Average initial weight, kg.[c]					Average
Tap water	52	51	50	51	51
ODML	51	51	51	51	51
Average	51	51	50	51	
Average daily gain, kg.					
Tap water	.79	.77	.73	.70	.75
ODML	.74	.73	.70	.71	.72
Average[d]	.76	.75	.71	.70	
Average daily feed, kg.					
Tap water	2.79	2.75	2.76	2.79	2.77
ODML	2.68	2.70	2.69	2.68	2.69
Average	2.73	2.72	2.72	2.73	
Average gain/feed					
Tap water	.285	.278	.265	.252	.270
ODML	.274	.273	.260	.265	.268
Average[e]	.279	.275	.262	.258	

[a]Dietary protein level provided by appropriate ratios of corn to soybean meal.
[b]Levels of 100 percent or 50 percent of the supplemental amounts of riboflavin, niacin, pantothenic acid, choline and B_{12} need to meet the suggested NRC (1979) dietary requirements for finishing swine.
[c]Each value represents an average for four pens of seven pigs each. Trial lasted 54 days.
[d]Differences between protein levels significant (P<.05).
[e]Differences between protein levels significant (P<.01).

Table 3. Effects of Source of Drinking Water and Dietary Supplemental Vitamins, Calcium, and Phosphorus on Performance of Finishing Pigs (Trial III)

Vitamins[a]	+	-	+	-	
Calcium and phosphorus[b]	+	+	-	-	
Average initial weight, kg.[c]					Average
Tap water	80	78	78	79	79
ODML	78	78	79	80	79
Average	79	78	78	79	
Average daily gain, kg.					
Tap water	.67	.66	.62	.62	.64[d]
ODML	.62	.56	.61	.62	.60
Average	.64	.62	.61	.62	
Average daily feed, kg.					
Tap water	2.45	2.54	2.45	2.47	2.48
ODML	2.43	2.21	2.47	2.42	2.38
Average	2.44	2.37	2.46	2.44	
Gain/feed					
Tap water	.237	.263	.254	.253	.261
ODML	.257	.255	.247	.255	.253
Average	.265	.259	.250	.254	

[a,b]See footnotes b and c, Table 1.
[c]Each value is an average for four pens of six pigs each. Trial lasted 35 days.
[d]Pigs with access to tap water gained faster (P<.05) than pigs with access to ODML for drinking water.

Table 4. Effects of Source of Drinking Water and Dietary Supplemental Vitamins, Calcium, and Phosphorus on Performance of Finishing Pigs (Trial IV)

Vitamins[a]	+	-	+	-	
Calcium and phosphorus[b]	+	+	-	-	
Average initial weight, kg.[c]					Average
Tap water	72	72	72	71	72
ODML	72	73	74	72	73
Average	72	72	73	71	
Average daily gain, kg.					
Tap water	.77	.87	.75	.75	.78[d]
ODML	.57	.56	.63	.67	.61
Average	.67	.71	.69	.71	
Average dialy feed, kg.					
Tap water	2.96	2.86	2.85	2.71	2.84[d]
ODML	2.28	2.42	2.44	2.63	2.44
Average	2.62	2.64	2.64	2.67	
Gain/feed					
Tap water	.263	.307	.265	.278	.278
ODML	.253	.231	.258	.255	.249
Average	.258	.269	.261	.266	

[a,b]See footnotes b and c, Table 1.
[c]Each value is an average for two groups of five pigs each. Trial lasted 41 days.
[d]Pigs with access to tap water gained faster and consumed more feed (P<.01) than pigs with access to ODML for drinking water.

Table 5. Summary of ODML Mineral Analysis of Four Consecutive Monthly Samples

Mineral	Monthly 1	2	3	4	Average
	Percent of ODML dry matter[a]				
Calcium	4.61	4.67	4.41	4.85	4.63
Phosphorus	3.74	3.58	3.56	3.54	3.60
Sodium	1.54	1.74	1.70	1.86	1.71
Potassium	5.00	5.04	4.95	4.87	4.96
Magnesium	1.45	1.32	1.37	1.34	1.37
Iron	0.41	0.44	0.47	0.45	0.44
Zinc	0.16	0.16	0.17	0.17	0.16
Maganese	0.04	0.04	0.04	0.04	0.04
Copper	0.01	0.01	0.01	0.01	0.01

[a]ODML dry matter content averaged 3.4 percent ranging from 2.7 to 4.1 percent.

Table 6. Average ODML Analysis Values for Nitrates, Total Solids, Temperature, and pH.[a]

Trial[b]	Season	C.O.D.[c], mg./l. Avg. (Range)	Nitrates, ppm Avg. (Range)	Total solids, pct. Avg. (Range)	Temperature, C Avg. (Range)	pH Avg. (Range)
I	Aug.-Nov.	--	452 (44-1600)	2.68 (1.89-3.47)	19.3 (14.5-21.0)	7.3 (7.1-7.6)
II	May-Aug.	40,058 (25,400 - 51,000)	520 (300-860)	4.12 (3.26-5.14)	26.0 (23-28)	7.8 (7.6-8.0)
III	July-Sept.	34,274 (13,421 - 50,130)	470 (156-720)	4.45 (2.94-5.75)	27.0 (23-39)	7.5 (7.1-8.0)
IV	Oct.-Dec.	17,529 (12,500 - 23,000)	870 (395-1220)	1.66 (1.20-2.62)	19.0 (15-22)	6.8 (6.2-8.3)

[a] Grab samples were taken weekly at a depth of about 15 cm. (total liquid depth was 45 cm.) about 23 meters downstream from the paddle wheel.
[b] Lengths of trials were 78, 54, 35 and 41 days, respectively, for I, II, III and IV.
[c] Chemical oxidation demand.

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College of Agriculture
Cooperative Extension Service

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Department of Animal Science

December, 1979

Effects of Management and Environment Modification on Performance of Finishing Swine

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An often-expressed concern of many swine producers with confinement facilities is the "7-months syndrome"--too many pigs not reaching market weight before 7 months of age. The 4 weeks prior to market weight have often been a period of apparent "slow down" in rate of gain.

The two studies reported here were conducted to evaluate whether (1) movement of pigs during the finishing phase to different pens in the same building or (2) mist spray for pigs on totally slotted floor during warm weather would be beneficial.

EXPERIMENTAL PROCEDURE

Experiment I. Two hundred forty finishings pigs were used. The four treatments were:

1. Pigs were in the same pen throughout the experiment.
2. Pigs were moved to a different pen when an average weight of 57 kg. (125 lb.) was attained.
3. Pigs were moved to a different pen when an average weight of 68 kg. (150 lb.) was attained.
4. Pigs were moved at both 57 and 68 kg. in weight.

Pigs were randomly allotted from outcome groups of 4 based on litter and sex to treatments within a building, with two replicates per building. Feed and water were available *ad libitum*.

Experiment II. The effect of a mist spray on performance of growing-finishing pigs in pens with concrete slats 5 inches wide spaced 1 inch apart in an enclosed, mechanically ventilated building, was studied during two summer seasons. In alternate pens, a fogging nozzle was attached to the rear partition so that when operating it discharged a fine mist over 0.81 square meter (9 sq. ft.) of floor space. The fogging system was thermostatically controlled to operate at 26°C (80°F) until the pigs reached 54 kg. (120 lb.) then 24°C (75°F) until the pigs reached 91 kg. (200 lb.). In the first summer pigs averaging 23 kg. (50 lb.) were randomly assigned from pairs based on weight and sex to pens without and with a fogging nozzle. Pigs were allowed 0.72 square meter (8 sq. ft.) of floor

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space each. In the second summer, the effect of reduced floor space (0.54 sq. m.; 6 sq. ft.) was also evaluated and initial weight of the pigs was 41 kg. (90 lb.).

In both experiments fortified corn:soybean diets, with 16 percent crude protein up to 54 kg. (120 lb.), and 14 percent from 54 kg. to 91 kg., were fed *ad libitum.*

Table 1. Summary of Results From Movement of Pigs During the Finishing Stage

	Control	Weight at pen location change: 57 kg.	68 kg.	57 and 68 kg.
Average initial wt., kg.[a]				
Bldg. A[b]	50	49	48	49
Bldg. B[c]	37	36	37	36
Bldg. C[d]	51	51	51	51
Average	46	45	45	45
Average daily gain, kg.				
Bldg. A	.74	.74	.76	.74
Bldg. B	.83	.83	.78	.80
Bldg. C	.71	.69	.69	.68
Average[e]	.76	.75	.74	.74
Average daily feed, kg.				
Bldg. A	2.30	2.35	2.32	2.36
Bldg. B	2.70	2.88	2.55	2.59
Bldg. C	2.67	2.56	2.45	2.45
Average[e]	2.55	2.60	2.44	2.47
Gain/feed				
Bldg. A	.321	.314	.327	.316
Bldg. B	.308	.290	.307	.308
Bldg. C	.269	.268	.264	.278
Average[e]	.299	.291	.299	.301

[a]Average final weights were about 95 kg.

[b]Fourteen pigs in each of two pens 2.7 meters x 6.7 meters (8 ft. x 20 ft.) in an open-front building that had a partially slotted floor. Period was April 12 to June 7, 1978.

[c]Eight pigs per pen in each of two pens 1.3 meters x 5.3 meters (4 ft. x 16 ft.) in an enclosed, mechanically ventilated building that had a partially slotted floor. Period was April 5 to June 21, 1978.

[d]Eight pigs in each of two pens 2.7 meters x 3 meters (8 ft. x 9 ft.) in an enclosed, mechanically ventilated building that had a totally slotted floor (concrete slats 12.5 cm. or 5 in. wide spaced at 2.5 cm. or 1 in.). Period was March 13 to May 9, 1978.

[e]There were no statistically significant differences among the four main treatments.

RESULTS

Experiment I. The results are shown in Table 1. There were no statistically significant differences among the four treatments in any of the buildings.

This suggests that moving to a "new" pen in the same building did not stimulate feed intake, and would not alleviate the "7-month syndrome." No abnormal behavior patterns were noted when pigs were moved.

Experiment II. Responses of finishing pigs to mist spray are indicated by the data in Table 2. During 1976 performance was similar in both treatments. In 1977, however, mist spray treatment significantly increased average daily gain. The mist also increased average daily feed and gain/feed, but not significantly.

Floor space allowance did not significantly affect performance. However, pigs having 0.72 square meter of space gained 4.5 percent faster and consumed 7.7 percent more feed per day than pigs allowed 0.54 square meter. On the other hand, pigs with only 0.54 square meter of floor space gained about 3 percent more per unit of feed consumed.

The fact that mist spray significantly affected average daily gain in 1977 but not in 1976 does not relate directly to the average inside high and low temperatures shown in Table 3. Indeed, the average high was slightly lower in 1977 than in 1976. However, the outside temperature was higher in 1977 (29.1^{o}C) than in 1976 (26.0^{o}C). The more critical fact, seemingly, would be the number of hours per week the inside temperature was above the mist-spray threshold (26^{o}C prior to 55 kg., 24^{o}C from 55 kg. to final weight), particularly during the last phase of each experiment. During the last 8 weeks (Table 3), the average number of hours per week of 24^{o}C or higher inside temperature was 57.0 in 1976 and 60.5 in 1977. For weeks 5 through 8, the weekly averages were 46.2 in 1976 and 60.2 in 1977. Thus, during 1977 the pigs were exposed to appreciably longer periods of high ambient temperatures (above 24^{o}C) during the period of gain from 70 to 92 kg. in weight.

SUMMARY

When finishing pigs were moved to a different pen at 56 or 68 kg., or both, there was no apparent effect on their performance in either an open-front building with a partially slotted floor; an enclosed building with partially slotted floor; or an enclosed building with totally slotted floor.

In one summer study, mist spray did not significantly affect performance of finishing pigs in a totally slotted, mechanically ventilated building. In the second summer study, rate of gain was increased significantly ($P<.05$), with feed intake and gain/feed nonsignificantly increased.

Table 2. Results of Using Mist Spray on Growing-Finishing Swine in a Mechanically Ventilated Building With Totally Slotted Floors and Pens Either 0.72 or 0.54 Square Meter in Size

	Mist spray[a]		
	-	+	Average
Summer, 1976			
(0.72 sq. meter floor space)			
Avg. daily gain, kg.[b]	.71	.70	.70
Avg. daily feed, kg.	2.58	2.52	2.55
Gain/feed	.275	.278	.276
Summer, 1977			
Avg. daily gain, kg.[c]			
0.72 sq. meter	.66	.72	.69
0.54 sq. meter	.63	.69	.66
Avg.[d]	.64	.71	
Avg. daily feed, kg.			
0.72 sq. meter	2.58	2.76	2.67
0.54 sq. meter	2.43	2.54	2.48
Avg.	2.50	2.65	
Gain/feed			
0.72 sq. meter	.257	.262	.259
0.54 sq. meter	.260	.272	.266
Avg.	.258	.267	

[a]Fogging nozzle thermostatically operated at 26 C, and above, room temperature until pigs reached about 54 kg, then at 24 C to 91 kg. The spray covered about 0.81 square meter of floor space.

[b]Each value is an average for seven pens of eight pigs each. Average initial weight was about 23 kg; final weight, about 91 kg.

[c]Each value is an average for six pens of eight pigs each. Average initial weight was about 47 kg. Final weight about 91 kg.

[d]Pigs with benefit of mist spray gained significantly (P<.05) faster than pigs with no mist spray.

Table 3. Ambient Temperatures (°C) During the Finishing Phase of Mist-Spray Experiment

	Inside[a]				Outside[b]			
	1976		1977		1976		1977	
Week	High	Low	High	Low	High	Low	High	Low
1	28	21	28	22	25	14	33	22
2	29	20	29	24	27	16	31	19
3	29	22	27	21	27	14	29	16
4	28	20	24	18	30	19	29	18
5[c]	27	20	26	19	27	13	27	18
6	27	21	23	17	26	12	27	15
7	28	20	28	22	27	12	28	17
8	23	17	27	20	21	18	29	18
Avg.	27.4	20.1	26.5	20.4	26.2	13.5	29.1	18.0
(°F)	(81)	(68)	(79)	(69)	(79)	(56)	(85)	(64)

[a]Temperatures were recorded with a 7-day hygrothermograph on the center aisle floor. Each value is an average daily high or low temperature for the 7-day period.

[b]Data from records of the Illinois State Water Survey Division, Champaign. Each value is an average daily high or low for the 7-day period.

[c]During the period of week 5 through week 8 the average number of hours per week that the inside temperature exceeded 24°C was 46.2 in 1976 and 60.2 in 1977.

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December, 1979

Estrus and Conception in Lactating Sows and Piglet Performance as Influenced by Limited Nursing

L. H. THOMPSON AND A. H. JENSEN

Rebreeding sows within 10 days after weaning is necessary if producers are to maintain rigid farrowing schedules. Reducing the interval from weaning to rebreeding or achieving some synchrony of estrus in weaned sows would help producers to control the breeding herd and increase the efficiency of use of the farrowing facility. The all-in, all-out concept of handling sows and their piglets has been shown to be the greatest advantage in baby pig survival and performance. As a result producers are concerned about estrous activity in sows after weaning.

The causes of delayed estrus or anestrus in sows include age, body condition, and season as well as genetic capacity. First-litter sows show the greatest tendency to breed late or not at all. Young sows that do not breed back soon are probably thin and less aggressive at the feed trough than older sows. Lactational stress is a major factor in preventing sows from cycling while they are still nursing pigs.

In order to determine if the stress of lactation could be reduced, half of the sows were separated from their piglets about 20 days after farrowing. The piglets were partitioned from their mother in the farrowing crate and were allowed to nurse only 30 minutes four times daily. The pigs were allowed to eat creep feed during the time spent in the partitioned areas. This procedure continued for 12 days. During this period the remaining half of the sows in each farrowing group were maintained with their pigs continually.

The sows were checked twice daily for signs of estrus. We looked for changes in behavior, especially their response to pressure applied on their backs. About one-third of the sows that were limit-nursed did come into estrus before their pigs were weaned. (Table 1.) For these sows the average time from the beginning of limit nursing to estrus was approximately eight days. After weaning, the limit-nursed sows that had not cycled during lactation generally came into estrus a day or two earlier than the sows that were with their pigs continually.

Piglet performance was of major concern in this study. Most producers would be reluctant to impose any treatment that would impair survival and performance of piglets just to get sows bred sooner. Piglets were weighed before the trial, at weaning, and two weeks after weaning.

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Table 1. Reproductive Performance of Sows

Item	Treatment: Limit nursed	Treatment: Control
No. of sows	26	26
Sows in estrus, pct.	88	92
Sows in estrus during lactation, pct.	31	0
Conception, pct.	81	90
Time from weaning to breeding, days	1.7	6.6

Piglet death loss during limited nursing or after weaning was not increased by the treatment, but pigs that were limit-nursed gained at a much slower rate while in the limit-nursing boxes (Table 2). After weaning the limit-nursed pigs gained much more rapidly and weighed nearly the same as control pigs by 14 days after weaning. The postweaning gain demonstrated by the limit-nursed pigs was largely due to their acceptance of creep feed before weaning, and the stress of limited nursing probably reduced the trauma of weaning. Overall piglet performance was not depressed enough to be a major concern.

Table 2. Weight Gain and Feed Consumption of Piglets

Item	Treatment: Limit nursed	Treatment: Control
No. of litters	26	26
Preweaning weight gain. kg.[a]	1.10	2.48
Postweaning weight gain, kg.[b]	3.94	3.06
Total weight gain, kg.	5.04	5.54
Preweaning feed intake, kg./pig[a]	.92	.31

[a]Total gain or feed consumption per pig during 12-day treatment period.
[b]Two-week period following weaning.

At this time the labor involved in carrying out a limit-nursing program is probably too expensive; however, the study does point out the significance of the stress of lactation especially as it may interfere with the reproductive performance of young or thin sows.

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December, 1979

Blood Groups in Swine

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Results of blood typing several hundred litters of pigs with reagents for 22 blood factors (A, O, Ba, Bb, Ca, Da, Ea, Eb, Ed, Ee, Ef, Eg, Ga, Gb, Ha, Ja, Ka, Kb, La, Lb, Lf, and Lg) indicate that blood types of boar, gilt, and piglets in a family can make a difference in litter size.

When a boar has a blood factor that a gilt lacks, it is possible that mating between them will result in incompatibility between the gilt and her piglets which will be harmful to the piglets. Blood types of piglets from a large number of such matings were compared to the blood types of their parents, and blood factors Bb, Ja, and Ka seemed to be especially important in incompatibility between the piglets and their dams. Such comparisons are complicated by the fact that when piglets are incompatible with their dams, it is because they have inherited different blood factors from their sire and their dam. They may therefore be less vigorous because of the incompatibility, but they will be heterozygous for the blood factor in question, and heterozygosity can be important for hybrid vigor. Therefore reduced vigor due to incompatibility may be offset by increased hybrid vigor. Evaluation of the importance of these conflicting effects is one of the goals of studies now in progress.

The Ha blood factor has been shown to be important in pig productivity in Illinois and elsewhere in the United States and Europe. Both gilt-piglet incompatibility and hybrid vigor seem to be involved in differences in productivity between different Ha types. The Ha factor is associated with susceptibility to PSS (porcine stress syndrome) in some litters. This association could be due to the same genes' being responsible for the Ha blood factor and PSS, or it could be due to close linkage of separate genes for Ha and PSS. In a research project in collaboration with Dr. L.L. Christian of the Animal Science Department at Iowa State University, we have been blood typing littermate pigs from a large number of litters which have been typed for PSS as identified by the pigs' developing muscular rigidity under halothane anesthesia. Data from these tests suggest that the genes for Ha and PSS are not the same, but are very closely linked. Further breeding tests are underway to gather more information concerning these alternatives. If the genes are closely linked and crossover types can be identified in which the undesirable effects of PSS have been eliminated, it may be possible to utilize Ha typing to select breeding animals for maximum productivity.

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December, 1979

Effects of Protein Level, Physical Form, and Content of Regular and Opaque-2 Corn on Utilization of Simple and Complex Diets by Weaned Four-Week-Old Pigs

K.L. ADAMS AND A.H. JENSEN

The most recent National Research Council (NRC, 1979) publication on nutrient requirements of swine recommends a dietary crude protein level of 20 percent for pigs weighing 5 to 10 kg. (11 to 22 lb.) and 18 percent for those weighing 10 to 20 kg. (22 to 44 lb.). Recommended levels of dietary lysine for the two size groups are 0.95 percent and 0.79 percent, respectively. The University of Illinois, however, recommends 20 percent crude protein and 1.0 percent lysine for pigs from 5 kg. to 14 kg. (10 to 30 lb.)

Three levels of protein, as well as other variables in the diets of weanling pigs, were compared in recent experiments at the University of Illinois.

EXPERIMENTAL PROCEDURES

Five experiments were conducted to evaluate 20, 18, and 16 percent dietary crude protein levels for pigs weaned at 4 weeks of age. Regular corn and Opaque-2 corn were compared in both simple and complex formulations, using all three protein levels. Diets were fed in either meal or pellet form. Performance in each of two nurseries was also compared. The 20 percent crude protein formulas are shown in Table 1. Feed and water were available at all times.

The numbers of pigs in the five experiments were 192, 192, 144, 96, and 168. Individual pigs were randomly assigned to treatment from outcome groups based on ancestery and weight. Equal numbers of replicates were in each of two nurseries--1C, which had a partially slotted floor with electric heat in the floor in the sleeping area and solid partitions between pens; and 1D, which had a totally slotted stainless steel floor and wire partitions between pens.

RESULTS AND SUMMARY

Dietary Protein level. Increasing the protein level significantly ($P<.01$) increased the average daily gain, with a greater increase occurring between 16 and 18 percent protein than between 18 and 20 percent protein (Table 2).

In all five experiments there was a significant difference in gain/feed due to protein level, indicating that increasing dietary protein level increased the efficiency of gain. There were no interactions between diet and protein level.

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Table 1. Composition of Basal Diets

Ingredient	Simple		Complex	
	Regular corn	Opaque-2	Regular corn	Opaque-2
			Percent	
Regular corn (8.8%)	63.70	--	47.85	--
Opaque-2 (10%)	--	65.70	--	49.85
Soybean meal (44%)	33.00	31.00	16.75	14.75
Rolled oats	--	--	20.00	20.00
Dried skim milk	--	--	10.00	10.00
Fish meal (Menhaden)	--	--	3.00	3.00
Dicalcium phosphate	1.50	1.50	1.00	1.00
Ground limestone	1.00	1.00	0.60	0.60
Trace mineralized salt	0.35	0.35	0.35	0.35
Illini vitamin mix	0.20	0.20	0.20	0.20
ASP-250	0.25	0.25	0.25	0.25
	100.00	100.00	100.00	100.00
Calculated, percent				
Crude protein[a]	20.00	20.00	20.00	20.00
Lysine	1.11	1.10	1.10	1.10
Calcium	0.77	0.78	0.77	0.77
Phosphorus	0.63	0.62	0.69	0.68

[a]The 18 and 16 percent crude protein levels were achieved by adjusting the quantities of corn and soybean meal.

Type of corn. When a simple diet formula was fed (Experiment 2), pigs receiving regular corn gained faster ($P<.05$) than those receiving Opaque-2 (Table 3). With both complex and simple diet formulas, feed intake of regular corn was higher ($P<.05$) than of the Opaque-2. However, gain per unit of diet consumed was greater ($P<.05$) for Opaque-2 than for regular corn diets.

Simple and complex diets. As shown in Table 4, there was no significant difference between these treatments in average daily gain, average daily feed, or gain/feed.

Effect of pelleting. In Experiment 1 pelleting significantly ($P<.005$) increased gain/feed (Table 5). There was a similar trend in the other two experiments in which meal and pelleting were compared. These results indicate that pelleting tended to increase efficiency of diet utilization.

Housing environment. As shown in Table 6, total performance was significantly ($P<.05$) better in building 1C (with partially slotted floors, electric floor heat in the sleeping area, and solid partitions between pens), than in building 1D (with totally slotted, stainless steel floors, and wire partitions). Pigs seemed to be more comfortable in building 1C. The heated floors and solid partitions in this building likely offered protection from air movement. Pigs in 1D had no such protection and probably expended more energy to maintain body temperature.

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Table 2. Effects of Dietary Protein Levels

	Dietary crude protein, pct.		
	20	18	16
Average daily gain, kg.[a]	.37	.36	.29
Average daily feed, kg.	.588	.600	.577
Gain/feed	.639	.606	.540

[a]Each value is an average for 259 pigs (5 experiments). Average initial weight, 7.0 kg.

Table 3. Regular vs. Opaque-2 Corn

	Corn	
	Regular	Opaque-2
Average daily gain, kg.[a]	.34	.33
Average daily feed, kg.	.55	.49
Gain/feed	.624	.636

[a]Each value is an average for 192 pigs (Experiments 1 and 2).

Table 4. Simple vs. Complex Diets

	Diet formula[a]	
	Simple	Comple
Average daily gain, kg.[b]	.36	.36
Average daily feed, kg.	.635	.631
Gain/feed	.562	.572

[a]See Table 1.
[b]Each value is an average of 192 pigs (Experiments 3, 4, and 5).

Table 5. Meal vs. Pellet Diet Forms

	Diet form	
	Meal	pellet
Average daily gain, kg.[a]	.35	.35
Average daily feed, kg.	.550	.567
Gain/feed	.607	.641

[a]Each value is an average of 273 (Experiments 1, 2, and 5).

Table 6. Response to Housing Environment

	Housing unit[a]	
	1C	1D
Average daily gain, kg[b]	.38	.29
Average daily feed, kg	.579	.464
Gain/feed	.648	.632

[a]Building 1C had partially slotted floors with electric floor heat in the sleeping area and solid partitions between pens. Building 1D had totally slotted, stainless steel floors and wire partitions.
[b]Each value is an average for 192 piglets (Experiments 1 and 2).

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Department of Animal Science

December, 1979

Every-Third-Day Feeding of Gestating Gilts and Sows

R.A. EASTER, D.H. BAKER, E.J. MICHEL AND J.K. RUNDQUIST

Control of feed intake is a practical problem of gestation nutrition programs. The sow housed in a comfortable, or thermoneutral, environment requires 5,500 to 6,500 kcal of metabolizable energy per day to support normal reproductive functions. This is about 4.2 pounds of a corn-soybean meal diet. If given access to a self-feeder, the sow will consume as much as 15,000 kcal of energy per day. Inevitably the sow becomes overweight and has difficulty farrowing. She tends to kill pigs by overlay and may present a breeding problem after weaning.

Intake is best restricted by hand-feeding individual sows. This provides maximum caretaker attention to the needs of individual sows but requires a major input of labor, a limited, costly resource on most farms.

There are four viable alternatives to hand-feeding: (1) Sows can be fed individually with automatic devices. (2) A bulky, low-energy diet can be fed free-choice, with utilizable calories restricted by the sheer physical mass of the feed. (3) Appetite-suppressing compounds can be used to regulate intake. (4) The pregnant pig can be allowed to eat a high-energy (corn-soybean meal) diet free-choice but for restricted time periods. This practice is referred to as every-third-day feeding and was first described by D.E. Becker at the University of Illinois in 1964.

Although every-third-day feeding has been adopted by a number of producers, several major questions remain. Is reproductive performance affected? Do first-litter gilts respond differently than second- and subsequent-litter sows? How much extra feed is being consumed? A series of experiments was conducted to evaluate these factors.

In each experiment the control animals were individually fed 4.2 pounds of a corn-soybean meal diet (Table 1) from breeding until farrowing. The every-third-day feeding regimens were imposed, on the average, at day 30 of gestation and continued until day 109 of gestation. Conventional management procedures were followed in the farrowing house. The pigs were weaned at 28 days of age and the sows were bred for the second parity on the second post-weaning estrus. Sows were fed the lactation diet (Table 1) *ad libitum*.

R.A. Easter is Assistant Professor and D.H. Baker, Professor, Department of Animal Science. E.J. Michel and J.K. Rundquist are former graduate research assistants.

Table 1. Composition of Gestation and Lactation Diets,

Ingredients	Diet	
	Gestation	Lactation
	Pct.	Pct.
Ground yellow corn	88.90	78.60
Soybean meal (48.5% C.P.)	9.00	18.75
Dicalcium phosphate	1.00	1.00
Ground limestone	.70	1.20
Trace mineral salt	.35	.35
Illini vitamin mix	.05	.10
Total	100.00	100.00
Calc. crude protein	12.00	16.00

The purpose of the first experiment was to evaluate reproduction of gilts and sows fed 4.2 pounds of diet per day or offered the 4.2-pound daily ration as a single meal of 12.5 pounds every third day. The results of this experiment are shown in Table 2. First-litter gilts fed 12.5 pounds every third day gained significantly less weight in gestation than their counterparts fed 4.2 pounds of diet daily. They tended to farrow fewer live pigs and the pigs weighed less at birth. The second-litter sows presented a different case. Reproductive performance was not depressed when the diet was fed as a single 12.5-pound meal every third day. These data indicate that the first-litter gilts require more than 12.5 pounds of diet if fed once every third day. This may be partially related to the maternal growth that occurs in the first parity independent of maintenance and the development of the products of conception.

Table 2. Reproductive Performance of First-Litter Gilts and Second-Litter Sows Fed 4.2 Pounds of Diet Daily or 12.5 Pounds Every Third Day During Gestation[a,b,c]

Criterion	Litter and gestation treatment			
	First litter		Second litter	
	ED[d]	E3D[d]	ED[d]	E3D[d]
Observations-gestation	80	81	45	48
Gestation wt. gain, lb.	85.8	65.3	56.5	48.4
Observations-lactation	77	78	39	43
Lactation wt. change, lb.	-26.4	-18.3	-21.8	-12.1
Lactation feed, lb.	258.9	266.2	310.4	320.1
No. pigs born/litter	10.7	10.7	11.3	11.3
Pigs born alive/litter	9.7	9.4	10.4	10.5
Pigs weaned/litter	8.4	8.0	9.1	8.7
Litter birth wt., lb.	29.5	27.3	35.9	34.3
Live Piglet birth wt., lb.	3.1	2.9	3.5	3.3
Litter weaning wt., lb.	114.4	106.3	134.9	134.2
Piglet weaning wt., lb.	13.6	13.2	14.7	15.4

[a]Data represent means for three breeding groups.
[b]Average weight at breeding was 325 and 385 lb. for gilts and sows, respectively.
[c]Only gilts and sows farrowing at least one live pig were included in the gestation data. Only those weaning at least one pig were included in the lactation data.
[d]ED is every-day feeding; E3D is every-third-day feeding.

In the second experiment both first-litter gilts and second-litter sows were given the opportunity to eat at self-feeders for 24 continuous hours in each three-day period. Reproductive performance was not affected by dietary feeding regimen (Table 3). Gilts fed every third day averaged 5.1 pounds of daily feed consumption compared to 4.2 pounds for the restricted gilts. Second-litter sows fed every third day gained significantly more weight during gestation than those fed 4.2 pounds daily. Their daily feed intake averaged 6.75 pounds.

Table 3. Reproductive Performance of First-Litter Gilts and Second-Litter Sows Fed 4.2 Pounds of Diet Daily or Free-Choice Every Third Day During Gestation[a,b,c]

	Litter and gestation treatment			
	First litter		Second litter	
Criterion	ED[d]	E3D[d]	ED[d]	E3D[d]
Observations-gestation	65	72	28	28
Gestation wt. gain, lb.	77.0	75.5	55.2	91.5
Gestation feed consumption (66 days), lb.	275.9	338.8	275.9	445.9
Observations-lactation	65	71	28	28
Lactation wt. change, lb.	-27.1	-24.6	-2.9	-18.0
Lactation feed, lb.	249.9	249.7	314.2	309.8
No. pigs born/litter	10.5	10.7	10.9	11.4
Pigs born alive/litter	9.4	9.5	10.0	10.7
Litter birth wt., lb.	31.5	31.5	33.9	36.1
Pigs weaned/litter	8.3	7.8	7.6	7.9
Litter weaning wt., lb.	119.9	114.6	113.7	127.2
Piglet weaning wt., lb.	14.5	14.7	15.0	16.1

[a]Data represent means from three breeding groups.
[b]Average weight at breeding was 319 and 376 lb. for gilts and sows, respectively.
[c]Only gilts and sows farrowing at least one live pig were included in the gestation data. Only gilts and sows weaning at least one pig were included in the lactation data.
[d]ED is every-day feeding; E3D is every-third-day feeding.

These findings support the use of an every-third-day feeding program but clearly indicate that first-litter gilts and second-litter sows must be managed differently. Gilts must be self-fed for a minimum of 24 hours in each three-day period. The producer can anticipate consumption of about 0.9 pound of additional feed per day when this program is followed. Second-litter sows reproduce satisfactorily when fed 12.5 pound every third day; they gain excessively and overeat when allowed to eat free choice every third day. Our findings suggest that the producer should restrict the period of access to the self-feeder to a time that will limit consumption to 12 to 13 pounds.

1979-10
University of Illinois at Urbana-Champaign
College of Agriculture — Agricultural Experiment Station
Cooperative Extension Service — Department of Animal Science
December, 1979

Calcium Chloride as a Feed Intake Regulator for Self-Fed Gilts During Gestation

G. M. WILLIS AND D. H. BAKER

With the cost of swine production continuing to increase rapidly, producers must look for ways to cut production costs. Because hand-feeding the sow herd is costly and labor-consuming, production costs would be reduced if the need for hand-feeding gestating sows could be eliminated. Self-feeding sows during gestation would be ideal. However, self-fed sows gain too much weight during gestation because of excessive feed consumption.

Attempts have been made to develop self-limiting gestation rations. In the past, high levels of dehydrated alfalfa meal have been included in self-fed rations to cut feed intake, but this has resulted in only limited success. Interval feeding has also been investigated.

More recently, calcium chloride ($CaCl_2$) has been suggested as an agent to limit the feed intake of self-fed sows. Work at the Swine Research Center has been directed toward establishing whether voluntary feed intake during gestation can be reduced by $CaCl_2$ in the diet of self-fed gestating gilts. Twenty-eight first litter gilts were started on experiment and fed corn-soy rations (Table 1) containing 0, 3.5, 4.0, or 4.5 percent $CaCl_2$ from breeding to 109 days gestation. The corn-soy diet containing no $CaCl_2$ was hand-fed at the rate of 4 pounds/head/day, whereas the $CaCl_2$ diets were self-fed.

When gilts were self-fed rations containing 3.5 percent $CaCl_2$, gain was similar to that of hand-fed gilts (Figure 1). Higher levels of $CaCl_2$ resulted in less gestation weight gain than is recommended. Although 3.5 percent $CaCl_2$ limited the gain of self-fed gilts to that of the hand-fed controls, feed intake was not similarly limited. Gilts receiving 3.5 percent $CaCl_2$ required one third more feed to gain the same weight as hand-fed gilts. Future studies will determine whether the increased feed requirement of $CaCl_2$-fed gilts is due to increased feed wastage or to decreased efficiency of feed utilization.

G.M. Willis is Research Fellow and D.H. Baker, Professor, Department of Animal Science.

Table 1. Composition of the Experimental Rations

Ingredient	Control	3.5% $CaCl_2$	4.0% $CaCl_2$	4.5% $CaCl_2$
		Percent		
Ground corn	85.8	82.7	82.7	81.7
Soybean meal	7.4	7.4	7.4	7.4
Corn gluten feed	4.0	4.0	4.0	4.0
$CaHPO_4$	1.5	--	--	--
$CaCO_3$	.9	--	--	--
TM salt	.35	.35	.35	.35
Illini vitamin mix	.05	.05	.05	.05
$CaCl_2$	--	3.5	4.0	4.5
NaH_2PO_4	--	2.0	2.0	2.0
	100.00	100.00	100.00	100.00
Crude protein, pct.	12.0	11.7	11.7	11.6
Calcium, pct.	.75	1.25	1.45	1.65
Phosphorus, pct.	.60	.73	.73	.73

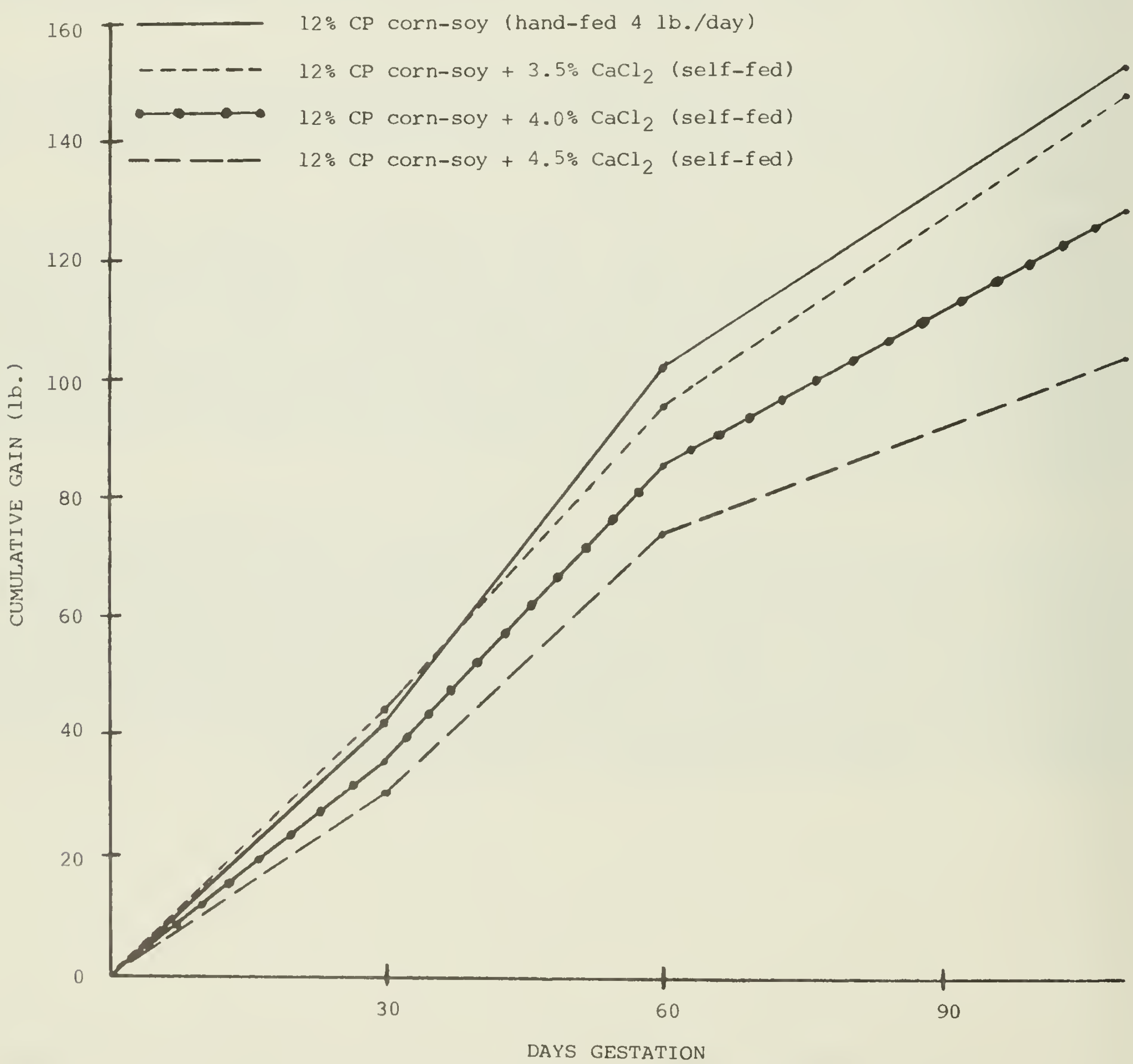

Figure 1. Weight gain of gilts fed $CaCl_2$ during gestation

University of Illinois at Urbana-Champaign
College of Agriculture — Agricultural Experiment Station
Cooperative Extension Service — Department of Animal Science
December, 1979

Efficacy of Several Antibiotics for Growth Promotion

R. A. EASTER, G. R. HOLLIS, J. A. CUARON AND H. COOK

It is clearly established that the response of pigs to specific antibiotics fed for growth promotion is variable and environmentally dependent. The study described herein was conducted to evaluate five specific antibiotic regimens at the Swine Nutrition Farm, University of Illinois. The results are not "final" answers but serve to indicate the effectiveness of the tested products under conventional management conditions at the Nutrition Farm.

PROCEDURE

A growth trial involving 144 crossbred barrows and gilts was conducted to evaluate the effectiveness for growth promotion of five antibiotic regimens: lincomycin;[1] the combination of chlortetracycline, penicillin and sulfathiazole;[2] bambermycins;[3] virginiamycin;[4] and tylosin.[5] The experiment was initiated in November of 1978 and terminated as pigs reached market weight during March of 1979. The starter phase was conducted in a heated nursery with pigs housed on elevated, slotted floor decks with solid sidewalls. During the growing and finishing phases the pigs were housed on solid concrete in a mechanically ventilated structure with a minimum temperature maintained at about 60° F.

The experimental treatments were as follows:

1. Basal diet, 18 percent crude protein starter, 16 percent grower, 14 percent finisher
2. As 1 + 20 gm./ton lincomycin throughout study
3. As 1 + 250 gm./ton CSP-250 throughout study

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[1] Lincomix[R], TUCO Division of Upjohn Co., Kalamazoo, Michigan, *not presently approved for growth promotion in swine.*
[2] CSP-250[R], Diamond Shamrock, Cleveland, Ohio.
[3] Flavomycin[R], American Hoechst Corp., Somerville, New Jersey. (The use of the bambermycins did not conform to the supplier's recommendation that the product be used only after pigs reach 75 pounds.)
[4] Stafac[R], Smith Kline Corp., Philadelphia, Pennsylvania.
[5] Tylan[R], Elanco Products Co., Indianapolis, Indiana.

R.A. Easter is Assistant Professor; G.R. Hollis, Associate Professor; J.A. Cuaron, Graduate Research Assistant; and H. Cook, Foreman of the Swine Nutrition Farm, Department of Animal Science.

4. As 1 + 2 gm./ton bambermycins throughout study
5. As 1 + 10 gm./ton virginiamycin throughout study
6. As 1 + 40 gm./ton tylosin to 125 pounds, then 25 gm./ton to market weight

The basal diets are shown in Table 1. These conventional corn-soybean meal formulations meet or exceed the pigs' known requirements for the starter, growing, and finishing phases. Diets were mixed in a 500-kg. horizontal paddle mixer that was thoroughly cleaned between batches. The mixed diets were stored in 80-pound, labeled bags until fed. Both feed and water were available *ad libitum* throughout the experiment.

The experimental unit was the pen group with six pigs (three gilts and three barrows) per pen. Each treatment was replicated four times with replicate blocks formed on the basis of initial weight. Within blocks, pigs were randomly assigned to treatments from six-pig outcome groups formed on the basis of ancestry, sex, and weight. Thus, the experiment was designed as a randomized complete block.

Performance data were subjected to analysis of variance. Treatment comparisons were made by the single degree-of-freedom procedure.

Table 1. Composition of Basal Diets

Ingredient	Crude protein level, pct.		
	18	16	14
		percent	
Corn	73.40	78.60	84.07
Soybean meal	23.86	18.75	13.60
Trace mineral salt[a]	.35	.35	.35
Vitamin premix[b]	.20	.10	.10
Limestone	.74	1.20	.78
Defluorinated rock phosphate	1.45	1.00	1.10
	100.00	100.00	100.00

[a]Contained the following per kg. of premix: Se, 28.6 mg.; I_2, 100.0 mg.; Cu, 2.29 gm.; Mn, 5.71 gm.; Fe, 25.7 gm.; Zn, 28.6 gm.; Co, 214 mg.; NaCl, 780 gm.

[b]Contained the following per kg. of premix: vitamin A activity, 3,300,000 U.S.P. units; vitamin D_2, 330,000 U.S.P. units; vitamin E, 22,000 IU, riboflavin, 1,100 mg.; d-panthothenic acid, 6.05 gm.; niacin, 16.5 gm.; choline chloride, 165.0 gm.; vitamin B_{12}, 17.6 mg.

RESULTS AND DISCUSSION

The performance data for this experiment are summarized in Table 2.

Interestingly, the greatest antibiotic response occurred during the growing period. Again, however, the response was only due to lincomycin and CSP-250 with CSP-250 superior ($P<.01$) to lincomycin for rate of gain. Lincomycin did not result in increased feed intake ($P>.05$) in either the growing or finishing period. Although there was a definite trend for lincomycin to increase gain during the finishing period, the effect was not significant. Feed efficiency was not improved by any of the antibiotic additions.

It is the opinion of the authors that this experiment afforded a good evaluation of the treatments under the management program at the Swine Nutrition Farm. The response to CSP-250 is consistent with our previous experience. We have evaluated virginiamycin in only one experiment previously (1974 Pork Industry Day) and found no response in the finishing period with a significant response in the growing period. We have no previous experience with bambermycins. We have consistently shown a response to tylosin in previous experiments and have used this antibiotic extensively in our herd diets in recent years. This may account for the lack of a tylosin response in this particular experiment. Pig performance throughout the experiment was very good. Five pigs failed to complete the experiment for reasons unrelated to dietary treatment. When evaluated across the entire experiment, both daily gain and daily feed consumption were increased ($P<.01$) by the addition of either lincomycin or the chlortetracycline-sulfathiazole-penicillin combination (CSP-250). There was no overall response ($P<.05$) to the addition of bambermycins, virginiamycin, or tylosin.

Table 2. Summary of Performance of Pigs Fed Several Antibiotics During Growth[a]

Criterion	Basal diet	+ Lincomycin	+ CSP	+ Bambermycins	+ Virginiamycin	+ Tylosin	Pooled. std. error
Average daily gain, kg.							
Starter	.48	.50	.50	.45	.45	.48	.016
Growing	.78	.83	.88	.79	.80	.81	.025
Finishing	.82	.88	.90	.82	.84	.84	.03
Overall	.72	.77	.80	.72	.73	.74	.017
Average daily feed, kg.							
Starter	.958	.961	.986	.904	.894	.924	.041
Growing	2.08	2.17	2.31	2.02	2.08	2.16	.07
Finishing	2.96	3.07	3.28	2.93	2.84	2.98	.10
Overall	2.15	2.24	2.38	2.10	2.13	2.17	.054
Gain:feed ratio							
Starter	.51	.53	.51	.50	.50	.53	.014
Growing	.39	.38	.39	.39	.39	.38	.38
Finishing	.28	.28	.28	.28	.29	.28	.006
Overall	.34	.34	.34	.34	.34	.34	.006

[a]Average initial weights were 8.82, 22.25 and 56.8 kg. for the starter, growing, and finishing phases, respectively. Average final weight for the finisher phase was 96.29 kg.

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December, 1979

Performance of Pigs on Low-Quality Waters

M.D. SHOOPMAN AND S.E. CURTIS

Groundwater contains many dissolved minerals. Depending on the minerals and their concentrations, low-quality water may have detrimental effects on animals, causing problems for producers who use water from certain deep wells.

Personnel of the Illinois State Water Survey are frequently asked for an opinion as to the suitability of a certain sample of groundwater for use as animal water. Available data have been used to establish general standards for animal drinking-water quality. Research in this area has shown that hogs are more susceptible to low-quality water than are sheep or cattle. However, the types and levels of salts that affect health and performance have not been clearly defined.

We conducted two experiments to study the effects that saline waters have on weanling pigs aged one to two months--the age at which they commonly start drinking considerable amounts of water. The salts studied were potassium and sodium sulfates and sodium chloride. Salt concentrations in the experimental waters were higher than those ordinarily present in Illinois groundwater of questionable quality for animal-watering purposes.

EXPERIMENT 1

Weanling pigs averaging 19 pounds body weight were given free access to a standard fortified corn-soybean meal starter diet. They were also given free access to either distilled water to which 2,500 mg. sodium sulfate and 2,500 mg. potassium sulfate had been added per liter, or distilled water with no added salts, for two weeks. Sulfate salts at concentrations as low as 1,000 mg./liter have a laxative effect, particularly in young animals. Sulfates also give the water a bitter taste.

Although pigs drinking the sulfate water had slightly greater average daily gain and gain-to-feed ratio (Table 1), there was no significant difference in any measure of performance. Water intake was greater for pigs drinking the sulfate water, especially during the first week of the trial; treated pigs consumed approximately 41 percent more sulfate water than control animals did distilled water. The difference diminished during the second week, as the pigs drinking sulfate water drank only 9 percent more.

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Fecal consistency of pigs drinking sulfate water was very soft throughout the test period, but this did not seem to be associated with any adverse effect. Feces of the control pigs remained firm throughout.

These results agree with those of others. Anderson and Strothers (1978) at Manitoba used younger pigs and a mixture of more salts, high in sulfates. The total dissolved solids content of their experimental water was 6,000 mg./liter, but this had no effect on the pigs' performance. Embry and coworkers (1959) at South Dakota used older pigs, averaging 37 pounds, and added up to 6,300 mg. of total dissolved solids, high in sulfate, per liter of experimental water. Pigs drinking the treated water slightly outperformed those drinking water with no added salts. Both research groups reported that pigs scoured, especially the first week, when drinking the saline waters.

EXPERIMENT 2

The purpose of this experiment was to see what effect 5,000 mg./liter of sodium chloride in the drinking water would have on pigs. The pigs' average starting weight was approximately 15 pounds. They were offered either saline or distilled water to drink, as well as a standard starter diet to eat, ad libitum for two weeks.

The pigs drinking water that contained added sodium chloride performed as well as those drinking distilled water. There was no significant difference in feed intake, average daily gain, or gain-to-feed ratio. The pigs drinking the treated water drank slightly more than those consuming distilled water. No scouring was noted in pigs drinking either water.

There has not been much research on the effect of sodium-chloride-treated water on pigs. Ballantyne (1957) at Alberta reported case histories of pigs that drank water containing large amounts of sodium chloride. In one case, pigs consuming water containing approximately 7,000 mg. of sodium chloride per liter scoured, and several died. In another, water from a well 475 feet deep contained approximately 1,800 mg. of sodium chloride and 497 mg. of sodium bicarbonate per liter, and it was suggested that this could have been the cause for depressed pig performance. Heller (1933) at Oklahoma added sodium chloride to the drinking water of hogs averaging 50 or 100 pounds. Hogs drinking a solution containing 10,000 mg./liter sodium chloride were not adversely affected, but water containing 15,000 mg. of this salt per liter caused death in the smaller pigs, and leg stiffness in the larger ones.

CONCLUSION

Results of our two experiments, coupled with other evidence from the scientific literature, indicate that waters containing up to 5,000 mg. of sulfate salts or sodium chloride--concentrations higher than commonly encountered in low-quality Illinois groundwaters--are not detrimental to weanling pigs. Pigs may consume more of such water than normal, and scouring may occur when sulfates are present, but this water does not seem to hinder their performance.

Table 1. The Effects of Sodium Chloride and Sulfate Waters On Weaned Pigs

Experiment 1	Control water	Sulfate water[a]
No. of animals	4	4
Average daily gain, lb.	.82	.93
Average daily feed, lb.	1.57	1.65
Gain/feed	.52	.56
Avg. daily water consumption, gal.	.50 (.34)[b]	.59 (.48)
Experiment 2	**Control water**	**Sodium-chloride water[c]**
No. of animals	4	4
Average daily gain, lb.	.82	.79
Average daily feed, lb.	1.32	1.43
Gain/feed	.62	.55
Avg. daily water consumption, gal.	.40 (.25)	.44 (.31)

[a]Distilled water was added to 2,500 mg. each of sodium sulfate and potassium sulfate until 1 liter of solution was present.

[b]Amount between parentheses is average daily water consumption the first week of the trial.

[c]Distilled water was added to 5,000 mg. of sodium chloride until 1 liter of solution was present.

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DECEMBER 1980

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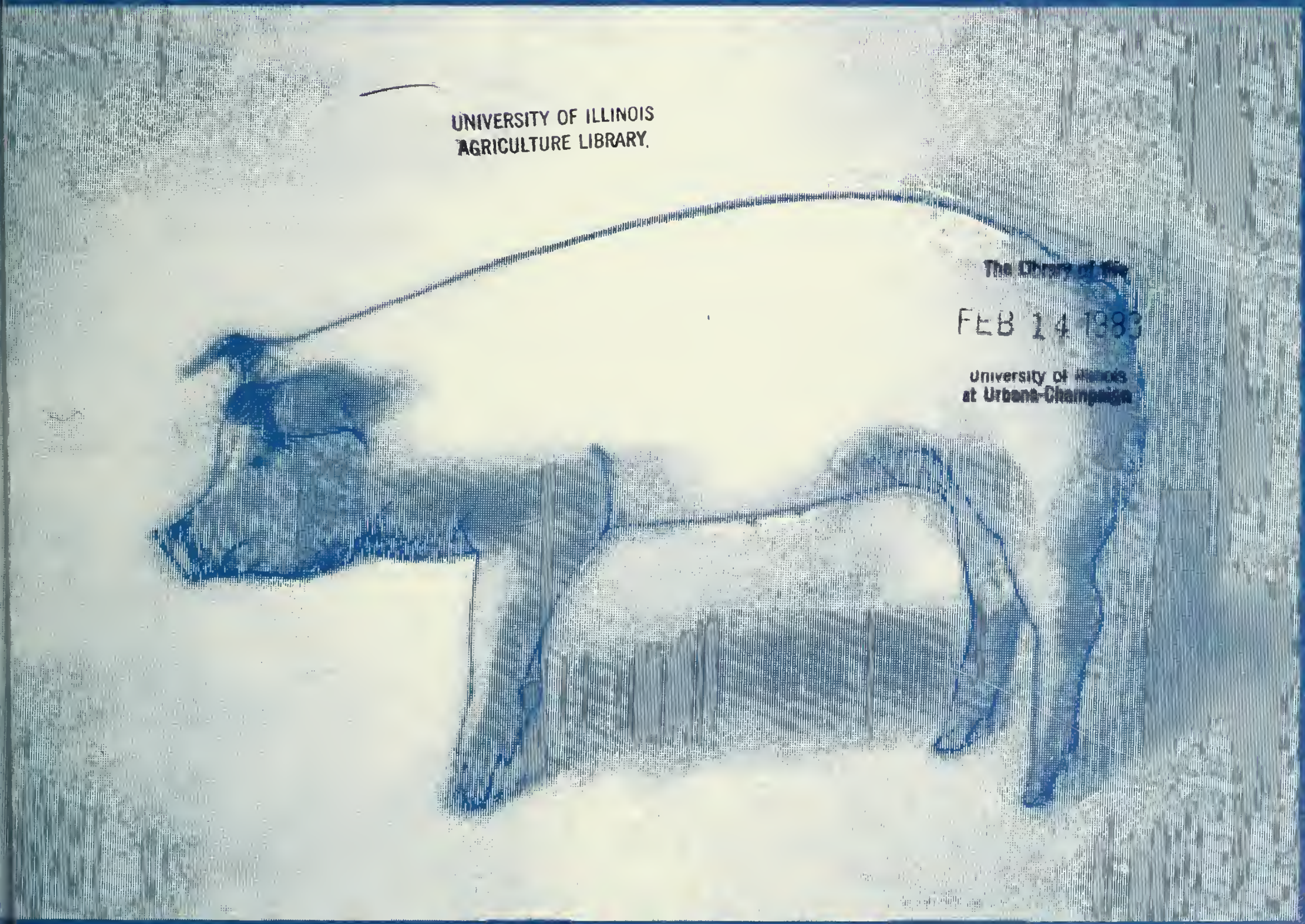

Contents

1980-1 Response of Nursing Pigs to Supplemental Heat
K.L. Adams, D.H. Baker, and A.H. Jensen

1980-2 Effect of Creep Feeder Location on Feed Acceptance by Nursing Pigs
J. Anleitner, T.F. Park, and A.H. Jensen

1980-3 Grain Replacement Value of Government Surplus Soda Crackers
D.H. Baker and S.A. Williamson

1980-4 Effects of Management and Environment for Sows and Litter on Pig Survival
D.C. Brammeier, T.F. Park, R.A. Gilbert, and A.H. Jensen

1980-5 Effects of Management and Feeding Level Between Weaning and Rebreeding on Reproductive Efficiency of Sows
D.C. Brammeier, T.F. Park, and A.H. Jensen

1980-6 Copper Toxicosis in Piglets Nursing Sows Fed High Copper Diets During Lactation
R.P. Chapple, R.A. Easter, J.A. Cuaron, and R.M. Forbes

1980-7 Amino Acid Supplementation of Low-Protein Diets for Starting, Growing, and Finishing Pigs
R.A. Easter, J.R. Corley, J.A. Cuaron, and S.A. Williamson

1980-8 Riboflavin and Sow Nutrition
M.W. Esch, J.M. Bahr, and R.A. Easter

1980-9 Estrus and Fertility in Lactating Sows and Piglet Performance as Influenced by Limited Nursing
K.J. Hanford, L.H. Thompson, and A.H. Jensen

1980-10 Performance of Young Pigs Allowed to Control Environmental Temperature Themselves
G.L. Morris, S.E. Curtis, and R.K. Balsbaugh

Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. WILLIAM R. OSCHWALD, Director, Cooperative Extension Service, University of Illinois at Urbana-Champaign. The Illinois Cooperative Extension Service provides equal opportunities in programs and employment.

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December, 1980

Response of Nursing Pigs to Supplemental Heat

K.L. ADAMS, D.H. BAKER, AND A.H. JENSEN

Supplemental heat, frequently supplied by a 250-watt bulb, is routinely provided for newborn pigs in farrowing units. The length of time this supplemental heat is beneficial will depend on room temperature, presence or absence of bedding, slotted or solid floors, ventilation, pig size and condition and other factors. But with increasing costs for energy, the length of time supplemental heat is provided becomes of greater economic concern. Thus, two experiments were conducted to evaluate the effects of supplemental heat, a 250-watt bulb suspended 45 cm (about 18 inches) above the pig sleeping area, for 0, 3, 6 or 21 days after birth.

EXPERIMENTAL PROCEDURES

Data were obtained during October to April in each of three successive winter seasons. A total of 162 litters over 10 farrowings were used. Four different farrowings units were used. In each of these units there were 15 stalls with floors of expanded metal (the rear 60 cm (24 inches) and the front 30 cm (12 inches) of the stall) and wood (120 cm (48 inches) section between the expanded metal sections). In the other unit there were 23 stalls on steel slotted floor (slats were 7.5 cm (3 inches) wide spaced at 1.25 cm (one half inch), except for expanded metal across the rear 60 cm of the stall floor. In all units there were solid partitions between stalls. When used, a heat lamp (250-watt bulb) was suspended 45 cm (18 inches) above the sleeping area adjacent to one of the stall partitions. Ambient temperature was maintained at approximately 21 C (70 F) by thermostatically controlled gas-fired space heaters. Personnel and management were common to all units. Pigs did not have access to creep feed and the dam and litter had access to separate nipple waterers.

In Experiment I, 29 litters were used to evaluate the effects of supplemental heat for pigs from birth to 21 days of age. Sows were randomly assigned prior to parturition to heat lamp and no heat lamp treatment. Dams were hand fed 1.6 kg (3.5 lb) of a fortified 14% crude protein corn:soybean meal diet at 8:00 a.m. and 3:00 p.m. on days two and three postpartum and then according to the schedule in table 1. Pigs were weighed within 24 hours of birth, at 3 days and at 21 days of age. Pig survival and body weight gain were the criteria used in evaluation. Weights of the dams were not obtained.

In Experiment II, 133 litters were used with each litter having the benefit of a heat lamp from birth to three days of age. Sows with seven or more live pigs at three days postpartum were randomly, within parity groups, assigned to treatment:

Table 1. Levels of Daily Feed for Gilts and Sows

Item	Days postpartum		
8:00 a.m., kg	3-5	6-11	12-21
Per gilt	1.82	2.27	2.73
Per sow	2.27	2.73	3.18
3:00 p.m., kg	3-8	9-14	15-21
Per nursing pig	0.23	0.34	0.45

Table 2. Response of Pigs from Birth to 21 Days to Supplemental Heat (Experiment I)

	Heat lamp[a]		
Item	-	+	
No. of litters	15	14	
Live pigs per litter, avg.			
At birth	9.7	9.1	
At three days	8.4	8.7	
At 21 days	7.9	8.1	
Avg. birth wt., kg.	1.44	1.44	
Pig loss, %			
Birth to day three	13.4	4.4	$P < .10$
Day three to day 21	5.9	6.8	
Birth to day 21	18.5	11.0	
Avg. pig gain, kg.			
Birth to three days	0.21	0.21	
Day three to day 21	3.29	3.48	
Birth to day 21	3.50	3.69	

[a]Ambient temperature of the farrowing unit was 21C at floor level. A heat lamp (250-watt bulb) was suspended 45 cm above the piglet sleeping area adjacent to one of the partitions.

(1) no heat lamp, (2) heat lamp for three additional days, (3) heat lamp for 18 additional days. The dams were weighed on days three and 21, pigs on days three, six and 21 postpartum. Feed consumption of the sow was regulated, a 14% crude protein fortified corn:soybean meal diet being fed at 8:00 a.m. and 3:00 p.m. daily according to the feeding schedule shown in table 1 chosen to approximate ad libitum feeding. A restriction imposed was that no additional feed was given until the previous feed was completely consumed. No creep feed was provided for the pig. Recordings were made daily of any illness or use of medication.

RESULTS

Experiment 1. Survival rate and weight gain of pigs without and with supplemental heat from birth to 21 days are shown in table 2. The percent of pigs that died within the first three days was 13.4 for the no heat lamp litters and 4.4 for the heat lamp litters ($P < .10$). Death loss for day three to 21 was 5.9 and 6.8%, respectively, and total loss from birth to 21 days, 18.5 and 11.0%. Average pig weight gain during the first three days was the same in both treatments. From day three to 21 the average gains were 3.50 (7.7 lb.) and 3.69 kg (8.2 lb.) for the no heat lamp and heat lamp groups, respectively.

Experiment II. Neither average feed consumption nor average sow weight loss was significantly affected by heat lamp treatment (table 3). The values in table 4 show that numbers of pigs per litter were similar among treatments. Percent death loss and percent of litters in which pigs died tended to decrease with increasing time of heat lamp use, but the differences were not significant.

Average pig weight and weight gain values are shown in table 5. By chance, average pig three day weight, both for all pigs and for pigs alive at 21 days, was greater ($P < .05$) for treatment three than for treatments one and two. Average weight at 21 days was significantly ($P < .05$) correlated with average initial weight. Thus, the data were analyzed after adjusting for average initial weight. Gain between days three and six was not significantly different among treatments, but total gain during both the periods day six to day 21 and day three to day 21 was greater ($P < .01$) for treatment three than for treatments one and two.

Table 5. Pig Weight and Weight Gain from Day 3 Through Day 21 After Birth (Experiment II)

Item	Treatment 1	Treatment 2	Treatment 3
Avg. 3-day weight, kg.			
All pigs	1.52^{a}	1.52^{a}	1.63^{b}
Alive at 21 days	1.55^{a}	1.56^{a}	1.66^{b}
Avg. gain, kg.			
Day 3 to 6	.46	.50	.51
Day 6 to 21	2.89^{c}	2.88^{c}	3.07^{d}
Day 3 to 21	3.35^{c}	3.38^{c}	3.61^{d}

[a,b]Values in same row with different superscripts were different, ($P < .05$).

[c,d]Values in same row with different superscripts were different, ($P < .01$).

Table 3. Average Sow Weight Change and Feed Consumption from Day 3 Through Day 21 Postpartum (Experiment II)[a]

Item	Treatment 1	2	3
No. of animals			
Sows	32	32	30
Gilts	12	11	16
Total	44	43	46
Avg. initial wt., kg.			
Sows	172	182	180
Gilts	143	153	145
Average	164	175	168
Avg. feed consumed, kg.			
Sows	99.9	102.5	101.7
Gilts	93.6	92.7	86.5
Average	98.2	100.0	96.4
Avg. wt. change, kg.			
Sows	-3.3	2.3	-1.0
Gilts	-1.14	-5.8	-6.8
Average	-2.7	0.2	-3.0

[a]No significant differences among treatments.

Table 4. Initial and Final Average Litter Size, Percent Death Loss and Percent of Litters with Death Loss (Experiment II)[a]

Item	Treatment 1	2	3
Avg. pigs per litter			
Initial	9.5	8.9	9.3
21 days of age	8.5	8.1	8.7
Death loss, %	10.3	9.1	6.8
Litters with death loss, %	52	44	43

[a]No significant differences among treatments.

In the absence of the heat lamp pigs spent more time huddled together and frequently lay close to or on the sow. Shivering was observed, particularly during the adjustment to the absence of the heat lamp, indicating discomfiture. In contrast, with the heat lamp, pigs laid on their sides and moved outward from under the heat lamp as they increased in size. There was, however, no significant occurrence of diarrhea or other illness in any of the treatments. There was no interaction between floor type and heat lamp treatment.

Survival of pigs from three days of age was not significantly affected by supplemental heat. Percent death loss and percent of litters in which pigs died tended to decrease with increased time of supplemental heat, but treatment differences were not significant.

CONCLUSIONS

These results suggest that in our 21C (70F) ambient temperature environment farrowing units, use of supplemental heat (a 250-watt bulb) was advantageous during the first three days postpartum. From day three, however, the absence of a heat lamp did not appear to significantly stress the pigs, although supplemental heat resulted in a pig gain advantage. This indicates that the pigs without supplemental heat used more dietary energy for homeothermy. On the other hand, feed intake and body weight loss of the sow would not strongly suggest that pigs on any of the treatments were stimulated to more frequent and/or vigorous nursing behavior.

In these experiments, based on concurrent feed, electricity and animal values, providing supplemental heat for the pigs beyond three or six days postpartum did not prove economically advantageous. But it must be emphasized that there were no apparent health problems in the sows and litters used. All farrowing groups farrowed on an all-in-all-out facility use schedule.

1980-2

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Department of Animal Science

December, 1980

Effect of Creep Feeder Location on Feed Acceptance by Nursing Pigs

J. ANLEITNER, T.F. PARK, AND A.H. JENSEN

It is generally believed that a nursing pig that has consumed an appreciable amount of dry feed will more readily adjust to weaning than nursing pigs that have not consumed dry feed. This would seem particularly critical for pigs weaned at three or four weeks of age. But, most often, a litter that is quite content with the quantity of milk provided by the dam will not usually voluntarily consume dry feed. Various flavoring substances and diet compositions have been evaluated as means of encouraging early dry feed consumption by the nursing pig. However, results are inconsistent for the three and four-week-old pigs. Also, waste of creep feed is of economic concern.

EXPERIMENTAL PLAN

Forty-eight litters were used in the evaluation of the effect of location of the creep feeder on dry diet intake by nursing pigs. The creep feeder, a two-hole feeder of four kilogram capacity, was located either at the front or rear corner of the farrowing stall area, and resting on the floor or elevated four inches above the floor. An 11-inch by 14-inch piece of 1/2 inch plywood with a 3/4-inch quarter round lip was placed under each feeder to prevent waste feed from falling through the slots. These sections were vacuumed daily to measure feed wastage from the feeder.

The corn:soybean-base creep feed was offered when a litter was 14 days of age. Either meal or pellet form of diet was fed. The trial was terminated when the litter was weaned at 28-days of age.

RESULTS

In this study, 32% of the creep offered was recovered as waste (table 1). Without the catch-boards under the feeders this feed would have fallen into the waste under the slotted floor. Elevation of the feeder significantly affected wastage, with more wastage from the feeders on the floor than from those four-inches above the floor. Feed in feeders on the floor was more frequently contaminated by feces and urine, and more likely to be rooted and knocked out by normal pig activity. Creep feed consumed per pig was not significantly affected by feeder location or elevation. Average intake per pig for the 14-day period was 144 grams, or 10.2 grams per day.

Intake of the pelleted creep feed was significantly higher than of the meal form (12.6 vs 7.5 grams per pig per day). There were no significant interactions among the factors evaluated.

SUMMARY

1. Consumption of creep feed between day 14 and day 28 of lactation was not significantly affected by either location (front or rear section of farrowing stall area) or by elevation (on-floor vs 4-inches above the floor).
2. Wastage from the creep feeder was significantly greater from the feeders on the floor than from those elevated four-inches above the floor. Over-all, 32% of the creep feed offered was wasted.
3. Consumption of pellets was significantly higher than consumption of meal.

Table 1. Effect of Feeder Location On Consumption of Creep Feed by Nursing Pigs[a]

Feeder location	No. of pigs Start	Finish	Creep feed, kg. per litter Fed	Wasted	Consumed	Intake per pig per day, grams
Front of crate[b]	196	193	1.62	0.50	1.03	9
Rear of crate[b]	203	193	1.91	0.65	1.26	11
Average			1.76	0.57	1.14	10
On floor[c]	198	190	2.02	0.77[d]	1.16	10
Elevated[c]	201	196	1.51	0.38	1.13	10
Average			1.76	0.57	1.14	10
Total average			1.76	0.57	1.14	10

[a]Forty-eight litters, average of eight pigs per litter, were used. Creep-feed was available from day 14 to day 28 post-partum.

[b]The 4.5 kg capacity, two-hole feeder was fastened to the side partition near the front or rear pen partition.

[c]Feeder was either resting on the floor or attached so that the bottom of the feeder was four-inches above the floor.

[d]Wastage was significantly ($P < .05$) greater from the on-floor feeder than from the elevated feeder.

Table 2. Comparison of Consumption and Wastage of Meal and Pellet Creep Feed

	Creep feed, kg per litter Fed	Wasted	Consumed	Intake per pig per day, grams
Meal[a]	1.35	0.47	0.87	7.5
Pellet[a]	2.19	0.68	1.42	12.6[b]
Average	1.77	0.57	1.14	

[a]Twenty-four litters, creep available from day 14 to day 28 post-partum.

[b]Significantly ($P < .05$) greater than for meal.

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December, 1980

Grain Replacement Value of Government Surplus Soda Crackers

D.H. BAKER AND S.A. WILLIAMSON

Location: Swine Nutrition Farm - Ramp (8/5/80 - 9/2/80)
Design: 3T x 3 pens x 10 pigs/pen

Diets (%):

	1[a]	2[b]	3[c]
Corn, ground	84.45	42.23	---
Crackers, ground	---	42.23	84.45
SBM (48% CP)	13.00	13.00	13.00
Defl-PO_4	1.25	1.25	1.25
$CaCO_3$	0.75	0.75	0.75
TM-salt	0.35	0.35	0.35
Illini vit. mix	0.10	0.10	0.10
Tylan-10	0.10	0.10	0.10
	100.00	100.00	100.00

[a]Basal 14% CP corn-soy
[b]As 1 - 50% replacement of corn with crackers
[c]As 1 - 100% replacement of corn with crackers

Results: (4 weeks on feed)

	1	2	3
R1	101	102	102
R2	118	119	117
R3	127	127	129
Avg. I.W. (lb.)	115	116	116
R1	1.06	0.94	0.48
R2	1.15	0.91	0.58
R3	1.14	0.94	0.60
Avg. daily gain (lb.)	1.07	0.93	0.55
R1	0.288	0.266	0.205
R2	0.285	0.287	0.223
R3	0.286	0.265	0.233
Avg. gain/feed	0.286	0.273	0.220

Analysis of Variance:

Source	d.f.	Mean square	
		Daily gain	Gain/feed
Total	8	---	---
Replicates (R)	2	0.0038	0.000114
Treatments (T)	2	---	---
linear	1	0.4760**	0.006534**
quadratic	1	0.0181*	0.000748
R x T	4	0.0016	0.000122

**P < .01; *P < .05

CONCLUSION

Pigs in this trial performed poorly on all treatments for reasons unknown. Nonetheless, it was clear that soda crackers are a poor source of energy for finishing pigs. The crackers were slightly burned on one side which could be taken as evidence that Maillard and other carbohydrate-protein or amino acid-amino acid reactions had taken place, thereby reducing the energy efficacy of the carbohydrate and the amino acid efficacy of the protein.

1980-4

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December, 1980

Effects of Management and Environment for Sows and Litter on Pig Survival

D.C. BRAMMEIER, T.F. PARK, R.A. GILBERT, AND A.H. JENSEN

Several studies at the University of Illinois have dealt with factors affecting occurrence and frequency of stillbirths, baby pig survival and pig performance to weaning (Jensen *et al*, 1976; Dziuk and Harmon, 1969; Harmon *et al*, 1972; Dziuk *et al*, 1972; Sprecher *et al*, 1974). And England (1962) had demonstrated that extra care and attention to environment and management during and subsequent to farrowing resulted in a 95% survival to weaning. Among several conclusions from these studies, one was particularly prominent -- herder supervision and attention at farrowing markedly reduced occurrence of stillbirths and increased survival rate. Government statistics (USDA, 1980) reveal that in Illinois the average number of pigs weaned per litter was 6.9 in 1978 and 6.8 in 1979. Estimates of post-farrow death loss range from 25 to 40%. Biologically and economically this loss is a disturbing production inefficiency, especially in view of the current intense concern over energy (which includes feed for animals) resources and utilization. Indeed, if the average litter size at weaning was increased by 1 pig, <u>182,300 fewer litters</u> per year would be needed in Illinois to produce the number of hogs presently marketed -- and, in addition, <u>41,000 fewer tons of feed</u> would be needed!

More recently, Canadian research (NHF, 1979) showed that a large percentage of pigs dying within three days of birth had apparently not nursed and thus basically died from starvation. Or if they had nursed, milk intake was insufficient.

To date, development of the large, specialized and modern "Pork Production Factories" pioneered by our Illinois producers has not, for various and logical reasons, programmed this kind of supervision. Indeed, labor demand and economic structure of the industry has not dictated such efforts.

It seemed justifiable, therefore, to investigate possible techniques for partially "automating" supervision of sows and pigs at farrowing to minimize environmental stress on newborn pigs, and to provide equal opportunity for newborn pigs to nurse.

EXPERIMENTAL PROCEDURE

Partially slotted floors in farrowing stalls had a 24-inch wide expanded metal section across the rear of the crate floor, a 10-inch wide section across

the front, with 2-inch by 6-inch boards in between. Half of them were modified so that a box was under each end of the rear expanded metal section. Each box was 16-inches wide, 24-inches long and 10-inches deep. The expanded metal top of the box was removed at least one day before expected farrow. The newborn pig, following its instinct to migrate to the udder area of the dam, would fall into the box. A 250-watt bulb was suspended above each box to ensure a very warm, dry and draft-free environment for the newborn. These lamps were removed when the pigs were removed from the boxes, and one was suspended 18 inches above the pig sleeping area to one side of the sow.

When parturition was complete, the pigs would be removed from the boxes and placed next to the sow's udder. If parturition was prolonged beyond four hours, the pigs would be removed from the boxes and placed with the sow.

Within 24 hours of birth, pigs were weighed, ear-notched, needle teeth clipped, tail docked and given an iron injection.

RESULTS

Data collected on 192 letters during a three-year period are shown in table 1. Percent of the pigs born live that died during the different periods post-partum was lower in the farrowing crates with boxes. Total death loss to 28 days of age was 23.4% in the regular farrowing crates, 16.7% in the farrowing crates with boxes. Also, the percent of litters with one or more piglet death loss was 28.1% in the regular farrowing crates, 15.6% in the farrowing crates with boxes.

In the regular farrowing crates, 33% of the pigs weighing 2.2 pounds or less at birth died within three days; in the farrowing crates with boxes the loss was 12.5% (table 2).

SUMMARY

1. Over a three-year period, the use of "catch-boxes" in farrowing crate floors resulted in fewer piglet death losses during the first three days post-partum. This trend was also true to 28 days of age.
2. The number of litters in which one or more piglets died was less in the box-crates than in regular crates.
3. A minimum box depth of 10 inches was required to keep the larger piglets from climbing out.
4. The piglets dried off quicker in the boxes than in normal crates.
5. Since the piglets in the boxes were presented to the dam as a group, each piglet had the opportunity to get its share of colostrum. A few gilts were reluctant to immediately accept the entire litter, particularly if farrowing had exceeded two hours.

CONCLUSION

The box-crate offers the opportunity to provide a more controlled environment for the newborn, and thus reduce piglet loss directly or indirectly caused by chilling.

The potential of a box-crate approach is likely to be utilized only when parturition time can be controlled. For example, if the dam could be treated on day 113 of gestation so parturition would occur between 8:00 a.m. and 12:00 noon on day 114, management control would be maximized.

Table 1. Summary of Evaluation of Boxes in Farrowing Crates for Confining Pigs Immediately After Birth

Floor design	Regular[a]				Boxes[b]			
Year	1977	1978	1979		1977	1978	1979	
				Total				Total
Number of litters	46	20	30	96	48	19	29	96
At farrow:				Avg.				Avg.
Total pigs per litter	9.6	8.8	9.1	9.3	8.9	8.9	9.7	9.1
Live pigs per litter	9.1	8.7	8.7	8.9	8.5	8.9	9.2	8.8
Death loss, % live pigs born								
Birth to 24 hours	4.4	3.4	4.2	4.1	2.4	3.1	2.6	2.6
24 to 48 hours	–[c]	6.9	5.3	5.9	–[c]	1.8	2.3	2.1
48 to 72 hours	–[c]	2.9	3.1	3.0	–[c]	1.8	1.9	1.8
Birth to 28 days	–[c]	23.6	23.3	23.4	–[c]	16.4	16.9	16.7
Litters with death loss between birth and 24 hours								
Number	13	5	9	27	6	4	5	15
% of total litters	28	25	30	28.1	12	21	17	15.6

[a]Standard farrowing crate with a 10-inch-wide expanded metal section across the front, a 24-inch-wide expanded metal section across the rear portion and 2" x 6" treated boards in the four-foot-wide section in the center section.

[b]Standard floor was modified to provide a box 24" x 16" x 10" deep under each end of the rear expanded metal section. The expanded metal section over the box was removed at farrowing time, then replaced when the piglets were removed from the boxes and placed with the sow to nurse. A 250-watt bulb was suspended 18 inches above each box. When the piglets were removed from the boxes, the bulbs were removed, and one was suspended 18 inches above the piglet sleeping area on one side of the sow.

[c]In the 1977 study the piglets were removed within three days of age and used in other experiments.

Table 2. Loss Within Three Days of Age of Pigs Weighing 2.2 Pounds or Less at Birth

	Number of pigs at birth		Loss by Day 3	
Farrowing crates[a]	Born live	Less than 2.2 lbs.	No.	%
Regular	262	18	6	33
With boxes	266	48	6	12.5

[a] See footnotes, table 1.

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December, 1980

Effects of Management and Feeding Level Between Weaning and Rebreeding on Reproductive Efficiency of Sows

D.C. BRAMMEIER, T.F. PARK, AND A.H. JENSEN

Feeding levels for and management of the sow from weaning to rebreeding vary considerably. Fasting the sows for 24 to 48 hours post-weaning is practiced by some producers, while on the opposite side full-feeding from weaning to rebreeding is practiced. Available research information is inadequate for all-inclusive recommendations.

The following experiment was conducted to evaluate (1) level of feed and (2) individual stall vs pen group for sows from weaning to rebreeding at the first estrus on days to estrus, conception rate and subsequent reproductive efficiency.

EXPERIMENTAL PROCEDURE

One hundred and six sows from five farrowing groups were used. At weaning, 28 to 35 days post-partum, sows were weighed and assigned on the basis of parity and weight to the following treatments:

Treatment	Feeding	Pen[a] or stall	Floor
I	ad libitum	Pen, 8 ft. x 16 ft.	Partially slotted
II	4 lbs/head/day	Pen, 8 ft. x 16 ft.	Partially slotted
III	ad libitum	Stall, 2 ft. x 7 ft.	Totally slotted
IV	4 lbs/head/day	Stall, 2 ft. x 7 ft.	Totally slotted

[a]Five or six sows per pen

Water was available at all times from nipple waterers. There were five or six sows per pen, and when ad libitum fed had continuous access to a two-hole self-feeder. When restricted fed, the quantity to provide an average of four lbs per head was placed on the solid concrete portion of the floor. The sows in stalls were fed, ad libitum or four lbs per day, in a feeder attached to the head of the

stall. Ration fed was fortified 12% crude protein corn:soybean meal mixture.

Sows were checked twice daily with a boar for signs of estrus. They were bred at the first estrus with two matings at least eight hours apart. After the second mating the sows were weighed and all were in individual stalls during gestation, each receiving four lbs of the diet once daily.

Any sow not evidencing estrus by ten days after weaning was removed from the breeding groups. However, those sows were observed daily for estrous symptoms for up to 21 days, then sold.

RESULTS

During the period between weaning and return to estrus ad libitum sows on the average essentially maintained weaning weight or gained slightly (table 1). Sows restricted to 1.8 kilograms (kg) of feed per day lost an average of four kg. These weight changes due to feed intake differed significantly ($P < .05$). Ad libitum sows ate more feed per day ($P < .01$) than the restricted fed sows, and within the ad libitum fed, sows in groups averaged a higher daily intake per sow than did sows in individual stalls.

Table 1. Effects of Feeding Level and Management Post-Weaning on Sow Weight Change and Days to Estrus

Feeding method	No. of sows	Sow weaning wt. kg	Wt. change to estrus kg	Feed per sow per day, kg	Days to estrus	Percent of sows in estrus by 10 days
Ad libitum						
Group	19	164	+3.2	4.1	5.1	74
Individual	22	159	-0.9	3.1	5.2	91
Avg.		162	+1.0[a]	3.5[b]	5.2	83
1.8 kg per sow per day						
Group	18	173(168)[c]	-5.0(-0.8)	1.8(2.9)	4.9(5.0)	72(73)
Individual	21	159(159)	-3.2(-2.0)	1.8(2.4)	5.0(5.1)	81(86)
Avg.		165	-4.0	1.8	4.9	77

[a]Weight change differed significantly ($P < .05$) between ad libitum fed and restricted fed sows.
[b]Ad libitum fed sows consumed more ($P < .01$) feed per day than did the sows fed 1.8 kg per day, Also, among the ad libitum fed sows, those in groups averaged more ($P < .01$) feed per sow per day than did the sows in individual stalls.
[c]Values in parentheses are averages for groups and individual management in both ad libitum and individually fed.

Number of days to estrus was not affected by treatment, however, the percent of weaned sows that showed estrus by ten days post-weaning was numerically higher for the sows in individual stalls than those in groups of five or six (86 vs 73 percent).

Treatment did not significantly affect occurrence of delayed estrus, anestrous on return to estrus after breeding (table 2). However, these effects were

noted in more group-sows than in sows in individual stalls (17 vs 9).

Gestation weight change was not affected by treatment between weaning and breeding (table 3). Number of pigs, total and live, at farrow favored the sows that had been restricted fed between weaning and rebreeding. Number of pigs weaned per litter was not significantly affected by treatment.

Table 2. Effects of Feeding Level and Management Post-Weaning on Occurrence of Delayed Estrus, Anestrous and Return to Estrus After Rebreeding

Feeding method	No. of sows	Delayed estrus No.	Delayed estrus Avg. days	Anestrous No.	Return to estrus No.	Return to estrus days
Ad libitum						
Group	9	-	-	5	4	5.6
Individual	4	-	-	2	2	4.5
Avg.		-	-	3.5	3	5.0
1.8 kg per sow per day						
Group	8	1	16.0(8.0)[a]	4(4.5)	3(3.5)	6.7(5.1)
Individual	5	1	18.5(9.2)	3(2.5)	1(1.5)	4(4.2)
Avg.		1	17.2	3.5	2	5.3

[a]Values in parentheses are average for group and individual management in both ad libitum and individually fed.

Table 3. Effects of Feeding Level and Management Post-Weaning On Performance Subsequent to Breeding

Feeding method	No. of sows	Gestation weight change, kg 0 to 25 days	Gestation weight change, kg 25 to 50 days	Number of pigs At farrow Total	Number of pigs At farrow Live	Number of pigs Weaned
Ad libitum						
Group	19	3.4	4.0	10.3	9.7	7.9
Individual	22	8.1	4.2	8.9	8.7	8.0
Avg.		5.9	4.1	9.5	9.2	7.9
1.8 kg per sow per day						
Group	18	3.1(3.2)[a]	4.7(4.3)	11.1(10.7)	10.3(10.0)	7.6(7.7)
Individual	21	4.4(6.3)	3.9(4.0)	11.3(10.1)	10.4(9.5)	7.9(7.9)
Avg.		3.8	4.3	11.2[b]	10.3[b]	7.7

[a]Values in parentheses are averages for group and individual management in both ad libitum and individually fed.
[b]Number of total and live pigs farrowed were higher ($P < .05$) for the sows fed 1.8 kg per day from weaning to breeding than for sows fed ad libitum.

SUMMARY

1. Sows in five successive monthly farrowings were used to evaluate effects of post-weaning feeding level and management on days to first post-weaning estrus, body weight change and subsequent reproductive performance.

2. Ad libitum fed sows consumed more ($P < .01$) feed per day than those limited to 1.8 kg per day.

3. On the average, ad libitum fed sows gained 1.0 kg in weight between weaning and onset of estrus. Sows limited to 1.8 kg of feed per day lost an average of 4.0 kg.

4. Neither number of days to onset of estrus nor percent of weaned sows showing estrus within ten days of weaning was affected by level of feeding.

5. Number of total and live pigs farrowed were higher ($P < .05$) for the sows fed 1.8 kg per day than for the sows fed ad libitum from weaning to breeding.

6. Percent of weaned sows showing estrus within ten days was higher (86%) in the sows in individual stalls than in sows in groups of five or six (73%).

7. When ad libitum fed, sows in groups consumed more feed than sows in individual stalls.

8. The number of sows that had delayed estrus or were anestrous or returned to estrus after breeding was higher in the sows in groups than in the sows in individual stalls (17 vs 9).

1980-6

University of Illinois at Urbana-Champaign

College of Agriculture
Cooperative Extension Service

Agricultural Experiment Station
Department of Animal Science

December, 1980

Copper Toxicosis in Piglets Nursing Sows Fed High Copper Diets During Lactation

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The inclusion of 125-250 ppm copper in growing and finishing rations provides a growth promotion effect and this addition has become commonplace in many European countries (Braude, 1975). It is also known that high levels of copper supplementation to diets for 10 to 14 day-old pigs result in depressed hemoglobin and hematocrit levels, decreased feed intake and weight gain and a marked increase in serum copper with accumulation in the liver (Gipp *et al.*, 1973). These effects seem to be exaggerated when iron is limiting.

Although the use of copper as a growth stimulant is prohibited in this country, the possibility that copper is put in swine diets for this purpose still remains. Since the protein levels of diets formulated for growing-finishing swine are particularly compatible with the protein requirements of lactating gilts and sows fed ad libitum, it becomes important to observe the effects of feeding high copper diets to sows on the iron and copper status of their piglets.

EXPERIMENTAL PROCEDURE

Thirteen first-litter, gravid gilts were randomly allotted into two groups. Six gilts were fed the control diet and seven gilts were fed the same diet supplemented with 200 ppm copper (Table 1) at the rate of 2.0 kg/day from day 109 of gestation until farrowing and ad libitum for the remainder of the 28-day lactation period. Colostrum and 7- and 28-day milk samples were analyzed for copper concentration. The piglets were weighed at birth, 14 and 28 days. Blood samples were obtained from the piglets at three and 28 days via vena cava puncture and hemoglobin, plasma copper and free iron determined. Within sex, one half of the piglets were randomly injected with 150 mg of iron as iron dextran at three days of age immediately after taking the first blood sample.

RESULTS

The data in Table 2 show that the addition of 200 ppm copper to lactation diets significantly ($P < .02$) increased the copper content of sow colostrum and milk. There was a tendency ($P < .15$) for milk copper to decline linearly as lactation progressed.

Table 1. Diet Composition

Ingredients, %	Diets: Control 0 ppm Cu	Cu-200 200 ppm Cu
Ground corn	84.05	83.95
Soybean meal	13.44	13.46
Defluorinated rock phosphate	0.83	0.83
Ground limestone	1.23	1.23
Vitamin premix[a]	0.10	0.10
Trace mineralized swine salt[a]	0.35	0.35
$CuSO_4 \cdot 5H_2O$	----	0.0786
	100.00	99.9986
Calculated contents		
Protein, %	14.00	14.00
Calcium, %	0.75	0.75
Phosphorus, %	0.50	0.50
Copper, ppm	12.90	212.90
Analyzed copper content, ppm	10.42	218.30

[a]See Appendix I.

Table 2. Milk Copper Content

Treatment	Day of lactation: 0	7	28	Mean
Control - 0 ppm added	1.453	1.456	1.135	1.348
Cu-200 - 200 ppm added	2.152	1.907	1.803	1.954[a]
MEAN	1.829	1.699	1.495	

[a]Significant ($P < .02$) treatment difference.

Table 3 presents the weight gains and hematological data obtained from the piglets. Pigs which had not received an iron injection exhibited significantly ($P < .01$) lower gains during the second half of the suckling period, which might be expected in view of the quite anemic condition of these pigs by this time. When the iron injection was withheld from pigs suckling dams on the control diet there was only a 9 gm/day depression in growth rate whereas this treatment produced a 50 gm/day depression when averaged over both sexes for piglets suckling sows fed the high copper diet. The iron injection completely ameliorated the deleterious effect of high copper supplementation on piglet weight gain.

Hemoglobin levels at day-28 showed an important diet X iron interaction. Where averaged over sex, hemoglobin levels were lower in pigs on the high copper with iron injection treatment than in control pigs, but when the iron injection was withheld the reverse was observed. Initially, an opposite result might have been expected. However, the data show that only when iron supplementation was eliminated in the presence of high copper were gains substantially reduced. The

Table 3. Weight Gain and Hematology of Piglets

Criterion	Diet / Sex / Iron inj.	Treatment Means: 0 ppm Cu, M, +	0 ppm Cu, M, -	0 ppm Cu, F, +	0 ppm Cu, F, -	200 ppm Cu, M, +	200 ppm Cu, M, -	200 ppm Cu, F, +	200 ppm Cu, F, -	Main Effects: Diet, 0 ppm	Diet, 200 ppm	Sex, M	Sex, F	Iron, +	Iron, -
No. pigs completing trial		10	11	10	9	10	6	12	12	40	40	37	43	42	38
Average daily gain (gm/day)															
Day 1 to Day 14		171	161'	170	169	154	121	186	152	168	158	155*	169	171	154
Day 14 to Day 28		194	179	192	179	193	107	189	142	186	164	176	174	192**	156
Total lact. period		183	171	181	174	174	114	188	147	177	161	165	172	181**	155
Hematology															
Hemoglobin (gm/100 ml)															
Day 3		8.4	8.5	8.5	8.6	9.5	8.4	8.7	8.7	8.5	8.9	8.7	8.6	8.8	8.6
Day 28		11.3	5.9	12.8	6.1	11.1	8.2	11.9	7.1	9.0	9.7	9.1	9.6	11.8**	6.7
Plasma copper (ppm)															
Day 3		.91	.85	.94	.94	1.16	.86	.94	.93	.91	.98	.95	.94	.99	.80
Day 28		1.86	1.92	1.80	2.04	2.17	2.07	2.06	2.15	1.90*	2.11	1.99	2.02	1.98	2.04
Plasma-free iron (ppm)															
Day 3		1.75	1.64	1.35	1.28	.98	.68	1.02	.99	1.52	.95	1.34*	1.14	1.26	1.20
Day 28		.83	.34	.95	.29	.64	.52	.68	.38	.61	.56	.58	.58	.77**	.37
No. pigs not surviving to weaning (28 days)		1	0	0	0	2	2	2	2	1	8	5	4	5	4

*P < .05; **P < .01.
[a]Diet X sex interaction (P < .05).
[b]Diet X iron interaction (P < .05).
[c]Diet X iron interaction (P < .01).
[d]Sex X iron interaction (P < .01).

result is a smaller pig at 28 days, consequently a smaller blood volume and higher than expected hemoglobin level. These data would indicate that the apparent copper toxicosis in the absence of supplemental iron is not a result of the precipitated anemia *per se*. The significant ($P < .01$) sex X iron interaction indicates that hemoglobin level in females is more sensitive to both the supplementation and absence of iron in early life.

Plasma copper was significantly ($P < .05$) higher at 28 days of age in pigs suckling sows fed diet Cu-200 regardless of sex or iron supplementation. There was an obvious increase of plasma-free iron in piglets given iron injections ($P < .01$). A diet X iron interaction similar to that observed for hemoglobin level was noted as well. Although the cause of death for the nine pigs that died during the course of this trial was not completely determined, eight of them were nursing sows fed the high copper diet.

No attempt was made to restrict piglets from access to the sow's feed or feces. It would appear improbable that the toxic symptoms produced in the piglets could be totally contributed to the observed small increase in milk copper. Therefore, the route of copper intake in the piglet under these conditions remains to be proven.

SUMMARY

Weight gain of piglets suckling sows fed a diet containing 200 ppm supplemental copper is significantly impaired where iron is not supplied early in life. Hemoglobin level, weight gain and plasma-free iron decline when supplemental iron is not provided for the piglet. The latter effects are exaggerated when piglets nurse sows being fed high copper diets during lactation.

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1980-7

University of Illinois at Urbana-Champaign

College of Agriculture
Cooperative Extension Service

Agricultural Experiment Station
Department of Animal Science

December, 1980

Amino Acid Supplementation of Low-Protein Diets for Starting, Growing, and Finishing Pigs

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The growing pig must obtain an adequate amount of each of the ten essential amino acids from the diet if growth rate is to be maximal. In practical terms it makes little difference whether the amino acids are added to the diet as synthetic chemicals or are obtained from the breakdown of feed proteins in the pig's small intestine.

At recommended crude protein levels the corn-soybean meal diet provides each of the ten essential amino acids in sufficient quantity to meet nutritional requirements. As crude protein levels are reduced, by replacing soybean meal with corn, lysine is the first amino acid to become inadequate. Synthetic lysine is relatively inexpensive and it is often economical to actually remove soybean meal from the diet and make up for the lysine deficit by adding synthetic lysine. If additional soybean meal is removed, tryptophan is the next amino acid to become limiting.

Presently, synthetic tryptophan is too expensive to consider for use in practical swine diets. It is conceivable, however, that advances in technology may substantially reduce the cost of tryptophan, giving the nutritionist the option of using both lysine and tryptophan in practical diets.

We have recently completed a series of 14 experiments involving 1,045 pigs. These experiments were designed to determine the potential value of synthetic tryptophan when used in conjunction with synthetic lysine in low-protein diets for pigs from four weeks of age to market weight. Low-protein diets are defined as diets formulated to contain less crude protein than is recommended by the NRC (1979).

Simple corn-soybean meal diets (table 1) were used. The pigs were penned in 5 or 10 pig groups on slotted floors in a totally enclosed nursery or growing and finishing building. Ambient temperatures were generally within the range of thermoneutrality. Feed was available ad libitum.

An 18% crude protein diet was used as the positive control in the series of experiments with starting pigs (4 weeks of age to 50 pounds). Performance of

Table 1. Percentage Composition of Experimental Diets

	Diets (Identified by Crude Protein Content, %)					
	Starter		Grower-Finisher			
Ingredient	14	18	10	12	13	16
Corn	83.00	73.55	93.45	88.72	86.56	79.81
Soybean meal (49%)	13.50	23.57	3.55	8.28	10.91	18.12
Dicalcium phosphate	1.70	1.46	1.35	1.25	1.18	1.03
Limestone	0.60	0.73	0.40	0.46	0.90	0.59
Trace mineral salt[a]	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin mix[a]	0.10	0.10	0.10	0.10	0.10	0.10
L-lysine·HCL	0.50	---	---	---	---	---
Ground cornstarch	0.25	0.24	0.80	0.84	---	---
Total	100.00	100.00	100.00	100.00	100.00	100.00
Analyzed composition						
Crude protein, %	14.10	18.20	10.01	11.98	12.91	16.00
Tryptophan, %	0.12	0.17	0.08	0.10	0.11	0.15

[a]See premix composition in reference material in Appendix I.

starting pigs fed a 12% crude protein diet supplemented with lysine and tryptophan was inferior to the performance of pigs fed the 18% standard. This suggests that there is a deficiency of at least one additional amino acid. In the second experiment the protein level in the low-protein diet was increased to 14%. Addition of lysine and tryptophan resulted in performance that was not different from that obtained with the 18% diet.

The data in table 2 are typical of the response obtained with the 14% diet and point to a potential limitation. In that data gain was not significantly improved by the addition of either methionine or threonine; however, feed efficiency was better ($P < .05$) when threonine was added to the 14% diet in addition to lysine and tryptophan. Four subsequent experiments have confirmed that the 14% crude protein diet is marginal in threonine and deficient in lysine and tryptophan. In our experiment the 14% diet contained .60% threonine by analysis. It is reasonable to suggest that a diet containing less than this amount would require threonine supplementation in addition to lysine and tryptophan. The quantity of lysine that must be added to the 14% diet can be calculated from the reports of Baker *et al.* (1975) and Easter and Baker (1980). It was established in these experiments that .04% L-tryptophan must be provided as a supplement to that naturally present in the 14% diet.

Researchers at the Ohio Experiment Station (Sharda *et al.*,1976) demonstrated that growing pigs fed a 12% crude protein diet supplemented with lysine and tryptophan will gain at a rate comparable to pigs fed a "standard" 16% growing diet. Thus the objective of initial growing pig experiment in this series was to determine if the protein level could be reduced to 10%. Addition of synthetic lysine and tryptophan to the 10% diet failed to restore performance to the level obtained with the "standard" 16% crude protein diet. Subsequent to this it was shown that the 10% diet is inadequate in total nitrogen needed for the synthesis of nonessential amino acids as well as specific essential amino acids. The 12% diet, however, if supplemented with .02% L-tryptophan (table 3)

Table 2. Performance of Starting Pigs Fed Low-Protein Corn-Soybean Meal Diets Supplemented with Amino Acids

Dietary treatment	Criterion[a] Daily gain, lbs/day	Daily feed, lbs/day	Gain/feed
18% crude protein corn-soybean meal	0.59[b]	1.32[b,c]	0.44[c]
14% crude protein corn-soybean meal + .5% L-lysine·HCL + .05% L-tryptophan	0.64[b]	1.38[b,c]	0.46[c]
As 2 + .24% DL-methionine	0.51[c]	1.23[c]	0.41[d]
As 2 + .13% L-threonine	0.66[b]	1.45[b]	0.47[b]

[a]Values are the mean of four replicates with five pigs per replicate. Average initial and final weights were 15.8 and 34.5 pounds, respectively.
[b,c,d]Means in the same column with different superscripts are significantly different ($P < .05$).

Table 3. Response of Growing Pigs to Graded Levels of Tryptophan Addition to a Lysine Fortified 12% Crude Protein Corn-Soybean Meal Diet

Dietary treatment	Criterion[a] Daily gain lbs/day	Daily feed, lbs/day	Gain/feed
16% crude protein corn-soybean meal	1.34[b]	3.74[b,c]	0.35[b,c,d]
12% crude protein corn-soybean meal + .25% L-lysine·HCL	1.14[c]	3.50[c]	0.33[d]
As 2 + .01% L-tryptophan	1.23[c]	3.70[b,c]	0.34[c]
As 2 + .02% L-tryptophan	1.38[b]	3.89[b]	0.36[b,c]
As 2 + .04% L-tryptophan	1.30[b,c]	3.45[c]	0.38[b]

[a]Values are means of four replicates with seven pigs per replicate; the average initial and final weights were 45.1 and 105 pounds, respectively.
[b,c,d]Means in the same column with different superscripts are different ($P < .05$).

and the proper quantity of lysine (Easter and Baker, 1980) will support pig performance that is equivalent to that obtained with the recommended (NRC, 1979) 16% crude protein diet.

Other workers (Sharda *et al.*, 1976 and Whalstrom and Libal, 1974) have clearly demonstrated that crude protein can be reduced to 10% in the finishing phase, provided lysine and tryptophan supplementation is adequate. We established that the tryptophan addition should be .02% of the diet in order to obtain the maximum rate and most efficient gain.

CONCLUSION

It does appear that synthetic tryptophan can be used in conjunction with synthetic lysine to substantially reduce the quantity of soybean meal used in

corn-soybean meal diets for starting, growing and finishing pigs. In general, the maximum reduction is four percentage units; from 18% to 14%, 16% to 12% and 14% to 10% for starting, growing and finishing pigs, respectively.

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1980-8

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December, 1980

Riboflavin and Sow Nutrition

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Riboflavin is a water-soluble vitamin that must be added to most practical swine diets. In swine a riboflavin deficiency results in poor growth (Krider *et al.*, 1949), premature farrowing, stillbirths, birth defects and neonatal death (Ensminger *et al.*, 1947). There is a general lack of quantitative information on which to base riboflavin recommendations for the breeding herd. Moreover, the effects of a riboflavin deficiency on the non-pregnant, post-pubertal gilt are unknown.

The experiments reported herein were conducted (1) to establish a test for riboflavin status that can be used in requirement studies; (2) to observe the effects of a riboflavin deficiency on the post-pubertal gilt and (3) to determine the riboflavin requirement for pregnancy in swine.

EXPERIMENT 1

Classically, riboflavin status has been measured using growth rate along with the riboflavin content of urine and blood. It has been a general observation that these methods are of limited value. In recent years a new procedure has been developed (Bamji, 1972) that has gained acceptance in human medicine as a valid technique for the evaluation of riboflavin status. This procedure is based on the action of glutathione reductase, an enzyme present in the erythrocytes or red blood cells. The test, commonly called the EGR test, is indicative of riboflavin status because the enzyme requires FAD (flavin adenine dinucleotide), a coenzyme that contains a flavin moiety derived from riboflavin, for its action. Since the enzyme is dependent upon FAD, the amount of enzyme activity is correlated with the amount of FAD present in the cell. This in turn is indicative of whether or not the animal is receiving sufficient dietary riboflavin.

The value obtained in the EGR test is expressed as a ratio of enzyme activities obtained in the following manner. First, a preparation of red blood cells is obtained from the pig being tested and the enzyme activity is measured. Then, FAD is added to the red blood cell preparation to determine total potential enzyme activity in the presence of adequate FAD. A ratio, referred to as an EGR activity coefficient, is then calculated:

$$\text{ACTIVITY COEFFICIENT} = \frac{\text{ACTIVITY WITH ADDED FAD}}{\text{ACTIVITY WITHOUT ADDED FAD}}$$

A low activity coefficient indicates the animal is receiving adequate riboflavin whereas a higher value indicates a riboflavin deficiency.

In the first experiment 13 barrows and 12 gilts averaging 180 pounds were used to determine baseline or "normal" EGR activity coefficients for healthy, well-nourished pigs. These pigs had received a corn-soybean meal diet from weaning that contained a minimum of 8 ppm riboflavin. Blood was taken by venapuncture on three consecutive days and subjected to assay. The resulting EGR activity coefficients are shown in table 1. These data show that the EGR test is not affected by sex of the animal and that there is little day-to-day variation in the values obtained. The average value for the tested population was 1.43 $\pm$ 0.11.

Table 1. Erythrocyte Glutathione Reductase Activity Coefficients of Barrows and Gilts Sampled for Three Consecutive Days

	Number	Day 1	Day 2	Day 3	mean
Gilts	12	1.42 $\pm$ 0.07[a]	1.44 $\pm$ 0.12	1.45 $\pm$ 0.13	1.43 $\pm$ 0.11
Barrows	13	1.43 $\pm$ 0.08	1.43 $\pm$ 0.09	1.43 $\pm$ 0.14	1.43 $\pm$ 0.10
	mean	1.43 $\pm$ 0.08	1.43 $\pm$ 0.11	1.44 $\pm$ 0.14	1.43 $\pm$ 0.11

[a]Data are expressed as means $\pm$ SEM.

EXPERIMENT 2

The second experiment was conducted to investigate the clinical effects of a riboflavin deficiency following puberty in gilts. Two experimental diets were prepared from the basal diet shown in table 2. The riboflavin deficient diet contained 0.77 ppm riboflavin; the riboflavin adequate diet contained 4.07 ppm riboflavin. Twenty crossbred pigs, ten per treatment, that had exhibited at least one estrus cycle were used in the experiment. Each gilt was confined in a narrow gestation stall on a slotted floor to prevent access to feces, a potent source of B-vitamins. The gilts were individually fed 4.2 pounds of the assigned diet each day.

The EGR activity coefficients (table 3) of the gilts fed the riboflavin deficient diets increased during the 110-day experiment. This indicates that a riboflavin deficiency was established and that the severity of the deficiency increased with time. The gilts were checked daily for estrous by exposure to a boar. The riboflavin deficient animals became anestrous (table 4) while those receiving the adequate diet continued to exhibit a normal estrus pattern. There were no other observed signs of a riboflavin deficiency such as hair or weight loss.

This experiment provided evidence, for the first time, that a riboflavin deficiency in swine does interfere with the estrus cycle. More importantly, this interference was observed despite the absence of any overt clinical signs of a deficiency. In addition, this experiment clearly established that the EGR activity coefficient is a sensitive indicator of riboflavin status in swine.

Table 2. Composition of Basal Diet

Ingredient	% of Total Diet
Cornstarch	60.66
Soybean meal[a]	25.00
Mineral mix[a]	4.00
Wood cellulose	2.00
Vitamin mix[b]	1.00
Corn oil	7.24
DL-methionine	0.10

[a]Each kilogram of mix contains the following: retinyl palmitate, 500,000 IU; cholecalciferol, 284,000 IU; DL-α-tocopheryl acetate, 12,000 IU; menadione, 20 mg; d-pantothenic acid, 2.64 g; nicotinic acid, 4.4 g; vitamin B_{12}, 4.4 mg; choline chloride, 220 g; folic acid, 200 mg; biotin, 20 mg; ascorbic acid, 30 g; pyridoxine, 250 mg; thiamin, 260 mg; and powdered cornstarch to 1 kilogram.

[b]Each kilogram of mix contains the following: (in grams) $CaHPO_4$, 650.05; NaCl (iodized), 159.96; K_2CO_3, 139.95; $MgCO_3$, 32.74; $FeSO_4 \cdot H_2O$, 10.00; $MnSO_4 \cdot H_2O$, 3.00; $CoCl_2 \cdot 6H_2O$, 1.00; $CuSO_4$, 1.00; NaF, 0.20; $ZnCO_3$, 2.00 and KI, 0.10.[2]

Table 3. Effect of Riboflavin Deficiency on the Erythrocyte Glutathione Reductase Activity Coefficient in Post-pubertal Gilts

Riboflavin Treatment	Dietary riboflavin ppm	No. Gilts	Days post-initiation of deficiency[a] 0	28	56	84	110
Adequate	4.07	10	1.38±0.06	1.40±0.06	1.41±0.07	1.40±0.08	1.42±0.15
Deficient	0.77	10	1.40±0.26	1.88±0.25	2.07±0.79	2.16±0.53	2.33±0.36

[a]Data are expressed as means ± SEM.

Table 4. Effect of Riboflavin Deficiency on Maintenance of Estrous Activity[a]

Treatment	Estrous cycles post-initiation of deficiency 1	2	3	4
Adequate riboflavin	10	10	9	9
Riboflavin deficient	10	9	2	0

[a]Post-pubertal female pigs were exposed to a male and observed daily for visual and behavioral signs of estrus.

EXPERIMENT 3

The third experiment was conducted to establish the riboflavin requirement for pregnancy in swine. Thirty crossbred gilts were bred and individually assigned on day-21 post-breeding to one of five dietary treatments. The basal diet (table 2) was supplemented with graded levels of riboflavin as shown below:

1. Basal diet, (as in experiment 2)
2. As 1 + 1 ppm riboflavin
3. As 1 + 2 ppm riboflavin
4. As 1 + 3 ppm riboflavin
5. As 1 + 4 ppm riboflavin

Each gilt was confined in a narrow gestation stall and fed 4.2 pounds of the assigned diet each day. Gilts were bled biweekly throughout pregnancy and riboflavin status established by the EGR test.

The results of the EGR tests are shown in table 5. As in the previous experiment the severity of the riboflavin deficiency increased with time after the initial feeding of the deficient diet. Analysis of the EGR data gave an estimated riboflavin requirement of 8.5 mgs per day. This can also be expressed as 4.4 ppm of a diet fed at the level of 4.2 pounds per day. The current riboflavin recommendation (NRC, 1979) is 5.4 mgs per day, an amount that is considerably less than that calculated to be required on the basis of our experiment.

Table 5. Effect of Riboflavin Deficiency During Gestation on Erythrocyte Glutathione Reductase Activity Coefficient

Available riboflavin, ppm	N	Days post-breeding			
		22	50	78	Parturition
0.77	5	1.39 ± 0.04[a]	1.70 ± 0.11	2.37 ± 0.09	3.14 ± 0.18
1.77	5	1.41 ± 0.03	1.67 ± 0.10	1.92 ± 0.16	2.76 ± 0.21
2.77	6	1.41 ± 0.06	1.53 ± 0.12	1.67 ± 0.13	1.79 ± 0.10
3.77	6	1.41 ± 0.06	1.48 ± 0.09	1.52 ± 0.11	1.57 ± 0.13
4.77	6	1.39 ± 0.04	1.42 ± 0.08	1.41 ± 0.16	1.42 ± 0.06

[a]Data are expressed as means ± SEM.

Consistent with earlier observations by Ensminger *et al.* (1947) gilts receiving the severely deficient diets, i.e., diets 1 and 2, delivered litters in which roughly half of the pigs were mummies and the remainder were stillborn.

SUMMARY

We have shown that the erythrocyte glutathione reductase assay for riboflavin status can be used effectively in swine. More importantly, it was shown that a deficiency of riboflavin will lead to a cessation of estrus in post-pubertal gilts, despite the absence of clinical signs of a riboflavin deficiency. And, finally, it appears that a pregnant gilt should receive a minimum of 8.5 mgs of riboflavin per day.

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Cooperative Extension Service

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December, 1980

Estrus and Fertility in Lactating Sows and Piglet Performance as Influenced by Limited Nursing

K.J. HANFORD, L.H. THOMPSON, AND A.H. JENSEN

Frequency of farrowing and litter size are two factors which determine the number of pigs produced per sow per year. Reduction of the interval from parturition to rebreeding will increase the frequency of farrowing; however, sows rarely exhibit estrus during lactation.

The stress of lactation and depletion of or lack of endogenous nutrient supplies may contribute to the anestrous state during lactation. Controlled intermittent suckling to induce estrus in lactating sows has produced mixed results. Smith (1961) reported that 12 hours of litter separation daily beginning on day 21 after farrowing induced fertile estrus during lactation, but Cole *et al*. (1972) did not observe estrus in any sows so treated.

The purpose of this experiment was to determine the influence of limited nursing from day 21 to day 33 or 28 of lactation on (1) the incidence of estrus in sows near the end of the lactation period and (2) the performance of piglets prior to and after weaning.

In Experiment I, sows were either assigned to a limited nursed (LN) group where they were allowed to only nurse their piglets for four 30 minute periods daily beginning at about 21 days after farrowing and continuing for 12 days to weaning or they were assigned to a conventionally handled control group.

In Experiment II, sows were either assigned to a limited nursed group where they were allowed to nurse their piglets four times daily for the first 3 days and then were reduced to three 30 minute nursing periods daily for 4 days to weaning or they were assigned to a control group.

Piglet weight gain and feed consumption during the treatment period and weight gain for the 2 weeks after weaning were also measured. Estrous activity in the sows was checked daily from the initiation of the treatment until 30 days after weaning.

Tables 1 and 2 contain sow performance data from Experiments I and II, respectively. More LN sows were in estrus during lactation than control sows; the difference being significant at the 1% and 7% levels in the first and second experiments, respectively.

Table 1. Reproductive Performance of Sows (12-Day Limited Nursing)

Item	Treatment: Limited nursing	Control
No. of sows	26	26
Sows in estrus, %	88	92
Sows in estrus during lactation, %	31^{a}	0^{b}
Conception rate, %	81	90
Days from weaning to rebreeding	1.7^{a} (±4.94)	6.6^{a} (±1.74)

[a,b]Means not bearing a common superscript are different ($P < .01$).

Table 2. Reproductive Performance of Sows (7-Day Limited Nursing)

Item	Treatment: Limited nursing	Control
No. of sows	37	37
Sows in estrus, %	86	86
Sows in estrus during lactation, %	14	0
Conception rate, %	86	88
Days from weaning to rebreeding	3.3^{a} (±2.58)	4.3^{b} (±.81)

[a,b]Means not bearing a common superscript are significantly different ($P < .05$).

The difference in treatment time appears to be of importance since most LN sows that were in estrus prior to weaning required more than 7 of the 12 days of treatment in Experiment I. In Experiment II, fewer sows were in estrus during lactation in spite of the fact that nursing frequency was reduced from four to three times daily in the last half of the treatment period.

Size of litters being nursed by sows in both groups ranged from four to 11 piglets and did not appear to have an influence on estrous activity during limited nursing. More multiparous sows were in estrus during lactation than primiparous sows. Hardy and Lodge (1969) indicated that changes in body condition from the previous lactation may influence ovulation rate. The primiparous sow normally has less body tissue from which nutrients can be drawn and therefore limited nursing as practiced in these experiments may not have provided ample relief from lactational stress. The number of sows failing to come in estrus after weaning and conception rate were similar in both parity groups and treatment groups.

The average interval from weaning to rebreeding was significantly shorter for LN than C sows in both experiments. The difference was due primarily to those sows which were in estrus during lactation.

Tables 3 and 4 contain piglet performance data from Experiment I and II, respectively. Data from one trial was deleted due to Exudative Epidermitis being contracted by some litters. Piglets in the limited suckling (LS) gained less weight and consumed more creep than control (C) piglets during the preweaning treatment period in both experiments.

Table 3. Weight Gain and Feed Consumption of Piglets (12-Day Limited Suckling)

Item	Treatment: Limited suckling	Treatment: Control
No. of litters	26	26
Preweaning gain, kg[a]	1.10[c] (±.52)	2.48[d] (±.57)
Postweaning gain, kg[b]	3.94[c] (±.85)	3.06[d] (±.99)
Total gain, kg	5.04 (±1.01)	5.54 (±1.15)
Preweaning feed intake, kg/pig[a]	0.92[c] (±.35)	0.31[d] (±.17)

[a]Twelve day period.
[b]Fourteen day period.
[c,d]Means not bearing a common superscript are different ($P < .01$).

Table 4. Weight Gain and Feed Consumption of Piglets (7-Day Limited Suckling)

Item	Treatment: Limited suckling	Treatment: Control
No. of litters	27	27
Preweaning gain, kg[a]	0.63[c] (±.48)	1.59[d] (±.54)
Postweaning gain, kg[b]	2.61 (±1.00)	2.53 (±1.11)
Total gain, kg	3.24[e] (±1.27)	4.12[f] (±1.36)
Preweaning feed intake, kg/pig[a]	0.85[c] (±.46)	0.46[d] (±.42)

[a]Seven day period.
[b]Fourteen day period.
[c,d]Means not bearing a common superscript are different ($P < .01$).
[e,f]Means not bearing a common superscript are different ($P < .05$).

The creep diet was altered between experiments by substituting sugar and dehulled rolled oats for a portion of the corn to improve palatability; therefore piglets in Experiment II consumed more feed per day than in Experiment I.

After weaning the LS piglets in Experiment I gained faster than C piglets so that total gain of piglets throughout Experiment I was not different.

In Experiment II, postweaning gain of C piglets was similar to that of LS piglets; therefore total gain for C piglets was greater than LS piglets throughout Experiment II. This response may have been due in part to the improved creep diet and the increased feed consumption near the time of weaning. Death loss in piglets was not different between treatment groups in either experiment. Therefore, piglet performance does not appear to be a significant problem in regard to limited nursing as a means by which sows can be induced to come into estrus during lactation. Further alterations of the preweaning environment and diet to improve weight gains of piglets exposed to limited suckling appears to be worthy of investigation.

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1980-10

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December, 1980

Performance of Young Pigs Allowed to Control Environmental Temperature Themselves

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Management of the pigs' thermal environment in the nursery is a critical task in pork production nowadays. Kept too cool, the pigs' feed-conversion efficiency falls and the animals become more susceptible to certain infectious diseases. Kept warmer than necessary, too much fuel is used.

The optimal environmental temperature in a nursery varies with the risks involved and with changes in relative prices of feed and fuel. It also depends on the preferences of each batch of pigs. A system of supplemental heating that could be controlled by the pigs themselves might have both biological and economic advantages.

Over ten years ago, two British scientists, B. A. Baldwin and D. L. Ingram, reported that young pigs held singly will operate in a consistent manner a switch activating a supplemental radiant heater that delivers heat bursts of a few seconds duration. More recently, we have reported that young pigs held in small groups do likewise. Moreover, they do so even when the duration of each supplemental-heat burst is as long as six minutes, suggesting that practical application of this thermoregulatory behavior might be feasible.

Operant apparatuses might be an energy-efficient means of controlling supplemental heat in animal houses during cold weather. Animals presumably regulate their thermal environments to be neither cooler nor warmer than is comfortable. The question remained as to whether young pigs in a practical setting would gain body weight at an acceptable rate and use feed efficiently in a thermal environment they themselves control.

An apparatus was designed so pigs weaned at three to four weeks of age could operate a gas-fired unit heater in a well-insulated, well-ventilated nursery on the Moorman Swine Research Farm during the 1979-80 winter season. Three consecutive trials, each involving eight pens of ten pigs, were conducted, starting 9 December (four-week trial), 11 January (three-week trial), and 5 February (four-week trial), respectively.

A single switch for heater operation was located in the same pen in all trials, hence one group of pigs controlled the heater. Over the switch were four heat lamps to provide instant reward and reinforcement of operant conditioning. Pigs readily learned to operate the heater, in a manner analogous to learning to operate a nipple waterer, except in this case supplemental heat was the reward, not water. The overriding thermostat was set at 26.7°C (80°F) when the pigs were introduced to the nursery, but the setting was reduced to 4.4°C (40°F) by the fourth day.

The heat lamps over the switch were set to stay on ten minutes--and the heater itself, eight minutes--each time a pig operated the switch. When the heat lamps were on, but the heater was off, switch operation had no effect.

The pigs caused environmental temperature (°C) inside the nursery to cycle each day. The average daily maximum temperature across trials was 23.2°C (73.8°F), which is in the range nursery thermostats are typically set. But the daily min-

	Trial		
	1	2	3
Daily maximum	22.5	23.1	23.9
Daily minimum	14.6	14.0	15.2

imum environmental temperature averaged only 14.6°C (58.3°F), which is considerably lower than most nurseries are kept and stands in stark contrast to the "hot nursery" held at 80° to 90°F the first couple of weeks after the pigs are weaned. Peak daily temperature occurred between 12 noon and 4 p.m. on 64 percent of the days, whereas the lowest daily temperature was reached between 10 p.m. and 2 a.m. on 60 percent of the days.

Inside median temperature each day varied in parallel with outside median temperature. For each 1° C change in outside daily median temperature, inside daily median temperature changed by .23° C in the same direction; variation among the three trials was in the range of .22° to .24° C.

Perhaps the most intriguing results of this set of trials had to do with the performance and health of the pigs. Even though the pigs were controlling their environmental temperature at an average daily level much lower than is now recommended for optimal animal performance, these pigs gained body weight quickly and used feed efficiently. Furthermore, the pigs remained healthy, with mortality being at the typical 2.5-percent level in each trial. After the usual growth

	Trial		
	1	2	3
Initial body weight, kg	6.6	7.8	6.8
Average daily gain, kg	0.35	0.36	0.33
Gain/feed ratio	0.60	0.50	0.63

check during the first week after weaning, pigs in all trials gained weight at the rate of around .5 kg (over 1 lb) daily.

These results suggest that, not only might operant supplemental heating reduce fuel use during cold weather nursery operation, but it also might result in relatively fast growth rate and relatively efficient feed conversion. Additional trials will be conducted in the 1980-81 winter season to study further this potential environmental-management tool.

Appendix A

Table 1. Porcine Vitamin Mix

Vitamin	Amt/lb. of Mix
Vitamin A, IU	227,273
Vitamin D-3, IU	11,364
Vitamin E, IU	5,454
Riboflavin, mg	273
d-Pantothenic Acid, mg	1,136
Niacin, mg	1,181
Vitamin B-12, mg	2
Vitamin K, mg	90.9
Choline Chloride, grams	56.8
Folic Acid, mg	90.9
Biotin, mg	9.09
Ascorbic Acid, grams	13.6
Pyridoxine, mg	113.6
Thiamine, mg	113.6

Table 2. Composition of Mineral and Vitamin Premixes Used in University of Illinois Swine Nutrition Research

Trace Mineral Salt	
Element	Content, %
Selenium	0.00286
Iodine	0.01
Copper	0.229
Manganese	0.571
Iron	2.57
Zinc	2.86
Cobalt	0.0214
Salt	78.0

Table 3. Illini Vitamin Mix

Vitamin	Amt/lb. of Mix
Vitamin A, IU	1,500,000
Vitamin D-3, IU	150,000
Vitamin E, IU	10,000
Riboflavin, mg	500
d-Pantothenic Acid, mg	2,750
Niacin, mg	7,500
Choline Chloride, mg	75,000
Vitamin B-12, mg	8

Table 3. Weight Gain and Hematology of Piglets

Criterion	Diet	Treatment Means								Main Effects					
		0 ppm Cu				200 ppm Cu				Diet		Sex		Iron	
	Sex	M		F		M		F				M	F	+	-
	Iron inj.	+	-	+	-	+	-	+	-	0 ppm	200 ppm				
No. pigs completing trial		10	11	10	9	10	6	12	12	40	40	37	43	42	38
Average daily gain (gm/day)															
Day 1 to Day 14		171	161	170	169	154	121	186	152	168	158	155*	169	171	154
Day 14 to Day 28		194	179	192	179	193	107	189	142	186	164	176	174	192**	156
Total lact. period		183	171	181	174	174	114	188	147	177	161	165	172	181**	155
Hematology															
Hemoglobin (gm/100 ml)															
Day 3		8.4	8.5	8.5	8.6	9.5	8.4	8.7	8.7	8.5	8.9	8.7	8.6	8.8	8.6
Day 28		11.3	5.9	12.8	6.1	11.1	8.2	11.9	7.1	9.0	9.7	9.1	9.6	11.8**	6.7
Plasma copper (ppm)															
Day 3		.91	.85	.94	.94	1.16	.86	.94	.93	.91	.98	.95	.94	.99	.80
Day 28		1.86	1.92	1.80	2.04	2.17	2.07	2.06	2.15	1.90*	2.11	1.99	2.02	1.98	2.04
Plasma-free iron (ppm)															
Day 3		1.75	1.64	1.35	1.28	.98	.68	1.02	.99	1.52	.95	1.34*	1.14	1.26	1.20
Day 28		.83	.34	.95	.29	.64	.52	.68	.38	.61	.56	.58	.58	.77**	.37
No. pigs not surviving to weaning (28 days)		1	0	0	0	2	2	2	2	1	8	5	4	5	4

*P < .05; **P < .01.
[a]Diet X sex interaction (P < .05).
[b]Diet X iron interaction (P < .05).
[c]Diet X iron interaction (P < .01).
[d]Sex X iron interaction (P < .01).

DECEMBER, 1981

SWINE RESEARCH REPORTS

Agricultural Experiment Station
Cooperative Extension Service
College of Agriculture
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Contents

1981-1 Evaluation of the Use of High-Oil Corn in Swine Diets
K.L. Adams and A.H. Jensen

1981-2 An Evaluation of Different Feeding Systems for Pigs at Weaning
F.X. Aherne and A.H. Jensen

1981-3 The Effects of Methods of Feeding on the Performance and Carcass Quality of Growing-Finishing Swine
F.X. Aherne, A.H. Jensen, and K.L. Adams

1981-4 Response of Four- or Five-Week-Old Weaned Pigs to Different Dietary Sources of Protein and Lysine Levels
F.X. Aherne, W. Warren, and A.H. Jensen

1981-5 Regulation of the Corpus Luteum in Swine
Janice Bahr

1981-6 Relative Efficacy of Glucose and Sucrose in Complex Pig Starter Diets
R.P. Chapple, J.A. Cuaron, and R.A. Easter

1981-7 Response of Growing-Finishing (Weanling to Market) Pigs to Lactobacillus Acidophilus (Probios Brand)
R.P. Chapple, R.A. Easter, and G.R. Hollis

1981-8 Storage Stability of Frozen Pork Patties
B.H. Chiang, H.W. Norton, and D.B. Anderson

1981-9 Dietary Protein-Calorie Ratios for Young Pigs
J.A. Cuaron, F.X. Aherne, R.A. Easter, A.H. Jensen, and T.F. Park

1981-10 Possible Role of Liver Enzyme Level and Reproductive Formation
Philip Dzuik

1981-11 Cottonseed Meal, Peanut Meal, and Fish Meal as Alternatives to Soybean Meal in Corn-Based Diets for Finishing Swine
A.H. Jensen, G.A. Acurero, and L.M. Penalver

1981-12 A Comparison of Flooring Materials in Farrowing Crates
A.H. Jensen and W. Warren

1981-13 Tumbling of Bacon
R.R. Motycka, J.A. Dippel, and G.R. Schmidt

1981-14 Value of Wheat Middlings in Swine Diets
V.L. O'Hearn, R.P. Chapple, J.A. Cuaron, and R.A. Easter

1981-15 Genetic Engineering in Swine Improvement: What Are the Prospects?
B.A. Rasmusen

1981-16 Evaluation of Different Methods of Utilizing High Moisture Corn in Diets for Gravid Swine
S.A. Williamson, R.P. Chapple, and R.A. Easter

Urbana, Illinois December, 1981

Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. WILLIAM R. OSCHWALD, Director, Cooperative Extension Service, University of Illinois at Urbana-Champaign. The Illinois Cooperative Extension Service provides equal opportunities in programs and employment.

USING THE METRIC SYSTEM

Most scientific publications require that units of measurements be reported in the metric system (kilograms, centimeters, etc.). The following conversion factors may be beneficial in helping to understand units of measurements that a reader may encounter in this report.

1 ounce = 28.50 grams	1 gram = 0.03527 ounce
1 pound = 453.6 grams	1 kilogram = 35.274 ounces
1 pound = 0.4536 kilogram	1 kilogram = 2.205 pounds
1 inch = 2.54 centimeters	1 metric ton (1000 kilograms) = 2205 pounds
1 foot = 30.48 centimeters	1 centimeter = 0.394 inch
1 yard = 0.9144 meter	1 meter = 39.37 inches
1 mile = 1.609 kilometers	1 kilometer = 0.6214 mile
1 square inch = 6.452 square centimeters	1 square centimeter = 0.155 square inch
1 acre = 0.4047 hectare	1 hectare = 2.471 acres
1 cubic inch = 16.387 cubic centimeters	1 cubic centimeter = 0.061 cubic inch
1 cubic yard = 0.7646 cubic meter	1 cubic meter = 35.315 cubic feet
1 fluid ounce = 29.573 milliliters	1 cubic meter = 1.308 cubic yards
1 liquid pint = 0.4732 liter	1 milliliter = 0.0338 fluid ounces
1 liquid quart = 0.9463 liter	1 liter = 33.81 fluid ounces
1 gallon = 3.7853 liters	1 liter = 2.1134 pints
	1 liter = 1.057 quarts
	1 kiloliter = 264.18 gallons

University of Illinois at Urbana-Champaign

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Evaluation of the Use of High-Oil Corn in Swine Diets

K.L. ADAMS AND A.H. JENSEN

The hybrid corns commonly used in swine diets contain, on the average, about 3.5% crude fat (oil). Corns with contents of 6 to 8.5% have been developed and currently such varieties can yield similar bushels of corn per acre as can good commercial hybrid corn varieties (Creech and Alexander, 1978). These high-oil corns also contain higher lysine levels than regular hybrid corn (.30 vs .24% lysine). Relatively little published information on the feeding value for swine of high-oil corns is available even though some tests were conducted 30 years ago at the University of Illinois (Terrill et al. 1951). Lynch et al. (1972) used corns varying about 2% in oil content in diets for finishing swine and performance was similar on both diets. However, Nordstrom et al. (1972) reported that, when the dietary corn contained between 6.7 and 8.4% oil, gains of growing pigs were more efficient than when regular corn (3.5% oil) was used in the diet.

The studies reported here are a part of a series of experiments designed to evaluate utilization of intact plant oils by the young pig.

EXPERIMENTAL PROCEDURES

Two experiments involving 186 pigs were conducted to determine the utilization of high-oil corn (HOC) by young pigs. In Experiment I the pigs averaged about 21 kg in weight and were on test for 28 days. In Experiment II pigs weaned at 28 days of age weighed about 10.5 kg and were on test for 28 days. Feed and water were available at all times in a totally slotted floor, environmentally regulated nursery unit. Experiment I was designed to determine if the intact oil was used efficiently. The regular corn-soybean meal diet (table 1) contained about 18% crude protein and .92% lysine to ensure that neither would be nutritionally limiting. Diets I through III had the same calorie:protein ratio while diet IV was formulated to be isolysine, but slightly lower calorie:protein ratio than with diets II and III. In Experiment II dietary crude protein and lysine levels were also above suggested requirements to ensure that neither would limit performance (table 2). The effects of roasting (at either 100 or 125°C) HOC was also evaluated. Pigs were weighed weekly.

RESULTS

The results of Experiment I are shown in table 3. There were no significant differences in average daily gain among dietary treatments. Average daily feed

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intakes were similar on the HOC diet and the regular corn-plus-corn oil diet, and both were significantly ($P<.05$) lower than for the corn-soybean meal diet (Diet I). These differences would reflect the different dietary caloric values. Gain/feed values for the HOC (Diet II) and regular corn-plus-corn oil (Diet III) diets were significantly ($P<.05$) higher than for Diet I. Gain/feed for Diet IV, same ingredients as Diet I except formulated to provide a higher lysine content, was nonsignificantly higher than for Diet I.

In Experiment II there were no statistically significant differences among dietary treatments for any criterion (table 4). However, average gain/feed for the HOC diets (Diets III through V) was .547, for the regular corn diet .517, a 5.8% difference. Roasting the HOC to 100 or 125°C (temperature of corn at discharge from the roaster) did not significantly affect apparent diet utilization.

SUMMARY

Two of a series of experiments designed to evaluate high oil corn (7.5% oil) in diets for swine have been reported. Based on rate of gain and feed efficiency, pigs weaned at four weeks of age used the high-oil corn efficiently.

With diets containing the same calorie-lysine ratios, high-oil corn was equal to regular corn (3.5% oil) plus corn oil in gain-feed values.

Roasting high-oil corn to 100 or 125°C, temperature of corn as discharged from the roaster, did not significantly affect apparent diet utilization.

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Table 1. Composition of diets, Experiment I

Corn[a]	Regular	High-oil	Regular	
Corn oil added	-	-	+	-
	%	%	%	%
Corn	73.89	73.74	71.32	73.01
Soybean meal	23.46	23.60	24.64	24.34
Corn oil	-	-	1.39	-
Lysine[b]	-	.01	-	-
Vitamin mineral antibiotic mix	2.65	2.65	2.65	2.65
	100.00	100.00	100.00	100.00
Calculated:				
Crude protein, %	18.0	18.3	18.3	18.3
Lysine, %	.92	.95	.95	.95
Kcal/kg	3932	4009	4010	3935

[a]Bomb calorimeter values for regular and high-oil corns were 3963 and 4066 Kcal/kg, respectively. Crude protein values were 8.8 and 9.2%; lysine values .24 and .30% respectively.

[b]Added as lysine-HCl, 78% L-lysine equivalent.

Table 2. Composition of diets, Experiment II

Corn[a]	Regular		High-oil		
Roasting temp., °C	-	-	-	100	125
	%	%	%	%	%
Corn	61.68	55.00	61.45	60.00	60.00
Soybean meal	35.00	38.50	35.20	35.20	35.20
Corn oil	-	3.20	-	-	-
Lysine[b]	.02	-	.05	.05	.05
Water[c]	-	-	-	1.45	1.45
Vitamin-mineral mix	3.30	3.30	3.30	3.30	3.30
	100.00	100.00	100.00	100.00	100.00
Calculated:					
Crude protein, %	22.1	23.1	23.1	23.1	23.1
Lysine, %	1.28	1.34	1.34	1.34	1.34
Kcal/kg	3827	4010	4006	4008	4008

[a]Bomb calorimeter values for regular and high-oil corns were 3860 and 4151 kcal/kg, respectively. Crude protein values were 9.1 and 10.7%; lysine values .22 and .27%, respectively.

[b]Added as lysine-HCl, 78% L-lysine equivalent.

[c]Added to replace the moisture lost during roasting.

Table 3. Summary of Experiment I

Corn	Regular	High-oil	Regular	
Corn oil added	-	-	+	-
Ration number	I	II	III	IV
Average initial weight, kg[a]	21.4	21.5	21.4	21.4
Average daily gain, kg	.84	.85	.82	.84
Average daily feed, kg[b]	1.67[1]	1.55[2]	1.56[2]	1.61[1,2]
Average gain/feed[b]	.503[1]	.549[2]	.530[2]	.521[1,2]

[a]Each value is an average for 3 pens of 8 pigs each.

[b]Values in the same row with different superscripts differ (P<.05).

Table 4. Summary of Experiment II

Corn	Regular		High-oil		
Roasting temp., °C[a]	-	-[c]	0	100	125
Average initial weight, kg[b]	10.4	11.1	10.4	10.8	10.8
Average daily gain, kg	.60	.63	.63	.61	.62
Average daily feed, kg	1.17	1.23	1.12	1.13	1.15
Average gain/feed	.517	.510	.561	.543	.536

[a]Temperature of corn as discharged from the roaster.

[b]Each value is an average for 4 pens of 4 pigs each.

[c]Corn oil added to make this diet isocaloric with the HOC diet.

December, 1981 1981-2
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An Evaluation of Different Feeding Systems for Pigs at Weaning[1]

F.X. AHERNE AND A.H. JENSEN

Like many other animal species, pigs show social interaction in feeding behavior; that is, they stimulate each other into eating. During the suckling period, pigs suckle as a group. It has been suggested that immediately after weaning, pigs may prefer to continue to eat as a group at least for a few days. Therefore, allowing sufficient trough space for a litter to eat as a group may encourage feed intake, especially for the reluctant feeder. It has also been suggested that pigs will more readily adjust to eating starter feed if they are fed a little feed on the floor for the first few days after weaning.

The objective was to study the effects of trough space and floor feeding on post-weaning pig performance.

MATERIALS AND METHODS

Ninety pigs were allotted, 10 to a pen, on the basis of sex and initial weight to one of three treatments:

1. Pigs were floor fed for the first week after weaning followed by full feeding from one 5-hole feeder per pen of 10 pigs.

2. Pigs were allowed two 5-hole feeders per pen of 10 pigs.

3. Pigs were allowed one 5-hole feeder per pen of 10 pigs.

The trial lasted 4 weeks. All pigs were fed the same 18% protein corn-soybean starter diet (table 1). Temperature of the barn was maintained at 23°C throughout the trial and water was available free choice.

RESULTS

The results of the trial are shown in table 2. Feed intake per pen of pigs during the first week or for all 4 weeks was not significantly influenced by trough space allowed. Feed disappearance in the first week was greater for pigs floor-fed but it can be assumed that much of that feed disappearance was due to

[1]Reprinted from the 60th Feeders' Day Report (1981), University of Alberta, Edmonton, Alberta, Canada, permission of Dr. F. X. Aherne, Department of Animal Sciences.

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feed wastage. Growth rate and feed conversion efficiency were not significantly different for the 2 trough-fed groups either in the first week or for the 4-week period. The pigs that were floor-fed during the first week of the experiment had the lowest growth rate and poorest feed conversion efficiency for the 4-week test period but pig performance was not significantly different from that of the trough-fed pigs.

SUMMARY

The results of this trial suggest that floor feeding does not improve pig performance during the first week after weaning but it does result in greater feed wastage. Allowing pigs enough trough space to eat as a group does not encourage them to eat as a group nor does it result in increased feed intake.

Table 1. Composition of starter diet

	%
Ground yellow corn	55.75
Soybean meal	18.00
Oat groats	20.00
Fish meal	3.00
Dicalcium phosphate	1.50
Ground limestone	1.00
Trace mineral salt	0.35
Vitamin mixture	0.20
Antibiotic	0.20
Calculated composition	
Protein	18.3
Lysine	0.9

Table 2. The effects of method of feeding on starter pig performance

	Feeding system		
Treatment	Floor	1 feeder	2 feeders
No. of pigs	30	30	30
Avg. initial wt., kg	5.9	5.9	5.9
Avg. daily gain, g			
First week	47	38	49
Four weeks	184	196	196
Avg. daily feed, g			
First week	230	136	130
Four weeks	378	357	376
Avg. gain/feed			
First week	.204	.279	.377
Four weeks	.487	.549	.522

December, 1981 1981-3

University of Illinois at Urbana-Champaign

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The Effects of Methods of Feeding on the Performance and Carcass Quality of Growing-Finishing Swine[1]

F.X. AHERNE, A.H. JENSEN, AND K.L. ADAMS

Maximum feed intake during the growing period (weaning to 55 kg) results in maximum deposition of lean tissue. However, during the finishing period (55 kg to 110 kg) more fat than lean may be deposited when hogs are fed ad libitum. It has frequently been reported that restricting feed intake during the finishing period will reduce growth rate but improve feed conversion efficiency and reduce percentage fat in the carcass. Most of these responses to restricted feeding have been observed with individually fed pigs. Whether restricted feeding would produce these effects with pigs penned in groups is less certain.

Because of the very high cost of feed in Europe there is a continual interest in finding feeding practices that will improve the feed conversion efficiency of market hogs. Currently there are suggestions that individual penning of pigs together with restricted feeding would improve feed conversion efficiency sufficiently to warrant the extra building costs of such systems. Restricted feeding continues to be the most popular feeding system in Europe but another method being tested recently is that in which pigs are fed free choice during the day but are denied access to feed during the period 4 pm to 8 am. Both of these feeding systems are reported to improve feed conversion efficiency and/or carcass quality.

The objective of these trials was to determine the effects of these feeding systems on the performance of finishing weight hogs.

MATERIALS AND METHODS

Experiment 1

One hundred and sixty-two crossbred hogs of an average initial weight of 58.8 kg were allotted on the basis of sex and initial weight to either of 3 feeding schedules.

1. Full feed 24 hours per day.
2. Full feed 8 am to 4 pm with no access to feed from 4 pm to 8 am.
3. Hogs were floor-fed twice daily at a level of 85% of the feed intake of hogs fed full feed.

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All hogs were fed a standard 14% protein corn-soybean finisher diet (Table 1). Water was available free choice. The hogs were penned in groups of 9 in solid floor pens. The temperature of the house was maintained at 20°C throughout the trial. The hogs were marketed as they reached 96 kg liveweight. Seventy-nine (49%) of the hogs reaching market weight were slaughtered at the University Meats Laboratory and the carcasses subjected to several carcass measurements. Carcass measurements were performed according to methods outlined in "Carcass Evaluation" publication PIH-42 of the Pork Industry Handbook.

Experiment 2

Sixteen crossbred hogs of an average initial weight of 58.3 kg were penned individually in 2' x 8' stalls and were assigned to either a restricted feeding or full feeding regimen. Treatment groups were balanced for sex and initial weight. Both groups were fed the same 14% protein corn-soybean finisher diet (Table 1). The full-fed group had feed available at all times and the restricted feed group were to receive 85% of the feed intake of the full-fed group in 2 equal meals per day. Water was available at all times. Temperature of the house was maintained at 20°C. The hogs were marketed as they reached 100 kg.

RESULTS

Experiment 1

Pigs fed a level of 85% of those fed ad lib grew at a significantly slower rate but feed conversion efficiency was unaffected by feed restriction (Table 2). Pigs fed free choice from 8 am to 4 pm consumed as much feed as pigs fed ad libitum for 24 hrs per day. Growth rate and feed conversion efficiency of these pigs was better than that of either the ad lib fed or restricted pigs. It is possible that these pigs cleaned up during the night any feed spilled during the day. The results of the carcass evaluation are shown in Table 3.

Feeding method did not significantly affect any of the carcass parameters measured.

Experiment 2

The pigs fed at a level of 85% of those fed ad libitum grew at a significantly slower rate but their feed conversion efficiency was also significantly better (Table 4).

SUMMARY

The results of these experiments suggest that restricting the feed intake does not improve feed efficiency or carcass quality of group fed hogs but does increase the time to reach market weight. In contrast a feed restriction system based on individually fed hogs does result in an improvement in feed conversion efficiency. If a system could be devised that would allow the easy withdrawal of feeders from pens at night it is probable that such a system would improve feed conversion efficiency of the hogs.

Table 1. Composition of diet fed in experiments 1 and 2

Ingredient (%)	
Ground corn (8.8% CP)	83.80
Soybean meal (47.5% CP)	13.00
Dicalcium phosphate	1.25
Ground limestone	.75
Trace mineral salt	.35
Vitamin premix	.80
Antibiotic (22 mg/kg)	.05
Protein (%)	14

Table 2. Performance of pigs in experiment 1

Feeding system	Full feed 24 h/day	Full feed 0800 to 1600	Fed 85% full feed
Number of pigs	54	54	54
Avg. initial weight, kg	59.51	59.23	59.33
Avg. final weight, kg	96.85	96.80	96.08
Avg. daily gain, kg	.68	.72	.60
Avg. daily feed, kg	2.57	2.60	2.21
Avg. gain/feed	.264	.277	.271

Table 3. Carcass measurements of hogs in experiment 1

Treatment	Full feed 24 h/day	Full feed 0800 to 1600	Fed 85% full feed
Live wt., kg	98.58	96.50	98.09
Carcass wt., kg	65.80	64.36	65.59
Carcass length, cm	78.71	78.46	78.76
Back fat, cm			
Last lumbar	2.06	1.78	1.65
Last rib	2.03	2.08	2.11
First rib	3.68	3.78	3.76
Average	2.54	2.54	2.49
Muscle, kg	38.36	37.66	38.65
Fat at 10th rib, cm	2.41	2.39	2.24
Loin eye area, sq cm	30.25	29.80	30.51
Muscle, %	54.10	54.20	54.5

Table 4. Performance of pigs in experiment 2

Treatment	Full feed	Restricted
Number of pigs	8	8
Avg. initial weight, kg	58	58
Avg. final weight, kg	100	98
Avg. daily gain, kg	.94	.85
Avg. daily feed, kg	2.82	2.18
Avg. gain/feed	.333	.390

December, 1981 1981-4
University of Illinois at Urbana-Champaign

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Response of Four- or Five-Week-Old Weaned Pigs to Different Dietary Sources of Protein and Lysine Levels

F.X. AHERNE, W. WARREN, AND A.H. JENSEN

Adams and Jensen reported in the 1979 Illinois Swine Research Reports that rate of gain of 7 kg pigs (weaned at 28 days of age) increased (P<.01) with increase of dietary crude protein. The increase was greater between the 16 and 18% levels than between the 18 and 20% levels. Gain/feed values, however, increased linearly with protein level. These results suggested that the National Research Council (NRC, 1979) recommended dietary crude protein and lysine levels for the 5 to 20 kg pig may be low. Thus three experiments were conducted to evaluate different protein sources and lysine levels for the young pig.

EXPERIMENTAL PROCEDURES

Six hundred and twelve pigs were used. In Experiments I and II they were weaned at 28 days and placed on the experimental diets, average weights about 7 kg. In Experiment III, the pigs were weaned at 28 days but not started on test until 35 days of age, average weight of 10 kg. The pigs were confined to .9 x 2.7 M pens on slotted floors. Room temperature was 26°C (80°F) for the first 7 days, then 24°C (75°F) for the last 21 days. The diets used are shown in table 1. To obtain a diet containing 20% crude protein and .95% lysine (NRC recommendations for 5 to 10-kg pigs) sesame meal, which is relatively high in protein but low in lysine, was included in the corn-soybean-based diet (C-SB-SM). Synthetic lysine (78% L-lysine) was then added to give dietary lysine levels of .95, 1.10 and 1.25%. To obtain the .95% lysine level with the corn-soybean meal diet (C-SB), an 18% crude protein level was used. A 20% crude protein level C-SB diet provided a level of 1.10% lysine, and synthetic lysine was then added to provide the 1.25% level. The meal diets were *ad libitum*, and each pen was equipped with a nipple waterer. Pig gain and feed consumption were determined weekly.

RESULTS

Data from Experiments I and II are shown in table 2.[1] During the first 7 days, average daily gain (ADG) tended to increase with increase in lysine level of each diet. Average daily feed (ADF) tended to increase with lysine level on the C-SB-SM diet but not on the C-SB diet. Gain/feed (G/F) value was lowest for each diet at the lowest lysine level, with values increasing at the 1.1 and 1.25% lysine levels.

[1] Average values of these two experiments were discussed by Aherne et al. (1981).

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For the 28-day period there was a trend toward increased growth rate with increase in lysine level, but differences were not significant. ADF did not differ significantly among diets. Pigs fed the C-SB-SM diet containing 1.25% lysine had a significantly better G/F then the pigs fed the C-SB diet with 1.1% lysine; G/F among the other five diets did not differ significantly.

Table 3 summarizes the combined comparisons of dietary protein source and of the three dietary lysine levels. There was no significant effect of protein source on any of the criteria measured. For both the first 7 days and the total 28-day periods ADG was lowest on the .95% lysine diet, with similar higher values for the 1.1 and 1.25% lysine diets. ADF was not affected by lysine level. G/F values increased ($P<.05$) with increase in lysine level during the first 7 days. During the 28-day period values were similar for the .95 and 1.1% lysine diets, higher for the 1.25% lysine diet.

In Experiment III the pigs were older and heavier at the start than in Experiments I and II; thus, ADG and ADF were higher than in Experiments I and II, especially during the first 7 days (table 4). Average daily gains were similar among dietary treatments during the first 7 days, but for the 28-day period the lowest rates on both diets were by the pig fed the 1.25% lysine diet. ADF and G/F values were variable among lysine level in the C-SB-SM diets. With the C-SB diets, ADF values tended to decrease and G/F values to increase with increase in lysine level.

Comparing dietary protein sources, ADG and ADF values were similar. G/F values, however, were signifcantly ($P<.05$) higher on the C-SB diets. Comparing lysine levels, ADG and ADF tended to decrease with increase in lysine level. Gain/feed values were nonsignificantly higher for the 1.1 and 1.25% lysine levels than for the .95% lysine level.

These results would support those of Adams and Jensen (1979) which indicated pigs weaned at four weeks of age and weighing about 7 kg require more than .95% dietary lysine for maximum efficiency of performance. They are also in agreement with data reported by Aherne et al. (1981) who fed barley-based diets to 7-kg pigs and found that growth rate and feed efficiency were significantly improved by increasing the dietary protein level from 18 to 20%. On both the 18 and 20% protein barley-based diets, increasing lysine level from 1.00 to 1.15% significantly improved growth rate and feed efficiency, increasing lysine level to 1.30% tended to depress performance.

SUMMARY

The data reported here suggest that pigs weaned at about 7 kg in weight, 4 weeks of age, require a minimum of 20% crude protein and 1.1% lysine in fortified corn-soybean meal-sesame seed meal and corn-soybean meal diets. With pigs weaned when 10 kg in weight, 5 weeks of age, .95% dietary lysine seemed to be adequate for gain, but with the corn-soybean meal diet gain/feed was higher at the 1.1 and 1.25% lysine levels.

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NRC. 1979. Nutrient Requirements of Domestic Animals. No. 2 Nutrient Requirements of Swine. Eighth Revised Ed. *National Academy of Science-National Research Council,* Washington, DC.

Table 1. Composition of diets

Protein source	Corn-sesame-soybean meals			Corn-soybean meal		
Dietary protein, %	20	20	20	18	20	20
Dietary lysine, %	.95	1.10	1.25	.95	1.10	1.25
Regular corn (8.8% C.P.)[a]	66.52	66.52	66.48	72.5	67.95	67.91
Soybean meal (48.5% C.P.)	22.41	22.41	22.41	24.2	28.60	28.60
Sesame meal (52% C.P.)	7.47	7.43	7.47	--	--	--
Dicalcium phosphate	1.50	1.50	1.50	1.50	1.50	1.50
Ground limestone	1.00	1.00	1.00	1.00	1.00	1.00
TM salt	.35	.35	.35	.35	.35	.35
Vitamin mix	.20	.20	.20	.20	.20	.20
ASP-20	.25	.25	.25	.25	.25	.25
Cornstarch	.30	.15	--	--	.15	--
Lysine HCl[b]	--	.19	.38	--	--	.19
	100.00	100.00	100.00	100.00	100.00	100.00

[a]C.P. = Crude protein

[b]Contained 78% L-lysine equivalent.

Table 2. Response of four-week-old weaned pigs's to different dietary proteins and lysine levels (Experiments I and II)

Protein source	Corn-soybean-sesame			Corn-soybean		
Dietary protein, %	20	20	20	18	20	20
Dietary lysine, %	.95	1.10	1.25	.95	1.10	1.25
Average initial weight, kg						
Experiment I[a]	6.8	6.9	7.0	6.7	6.9	6.9
Experiment II[b]	7.2	6.5	7.5	7.2	7.4	7.5
Average	7.0	6.7	7.2	6.9	7.1	7.2
Average daily gain, kg						
First 7 days						
Experiment I	.18	.14	.18	.14	.21	.19
Experiment II	.17	.24	.25	.22	.22	.22
Average	.17	.19	.21	.18	.21	.20
28 days						
Experiment I	.43	.42	.46	.40	.42	.44
Experiment II	.34	.40	.41	.36	.38	.38
Average	.38	.41	.43	.38	.40	.41

(Continued)

Table 2 continued

Protein source	Corn-soybean-sesame			Corn-soybean		
Dietary protein, %	20	20	20	18	20	20
Dietary lysine, %	.95	1.10	1.25	.95	1.10	1.25
Average daily feed, kg						
First 7 days						
Experiment I	.34	.30	.34	.32	.39	.28
Experiment II	.28	.35	.36	.44	.39	.34
Average	.31	.33	.35	.36	.38	.31
28 days						
Experiment I	.70	.68	.69	.67	.69	.70
Experiment II	.60	.71	.65	.64	.73	.70
Average	.50	.69	.67	.65	.71	.70
Average gain/feed						
First 7 days						
Experiment I	.534	.467	.521	.441	.537	.668
Experiment II	.589	.675	.697	.531	.596	.637
Average[c]	.561	.571	.609	.486	.566	.652
28 days						
Experiment I	.616	.619	.662	.593	.606	.628
Experiment II	.567	.562	.631	.558	.520	.543
Average	.591	.590	.646	.575	.563	.585

[a]Each value is an average for five pens of six pigs each.
[b]Each value is an average for four pens of six pigs each.
[c]Average gain/feed values among lysine levels differed (P<.05).

Table 3. Combined data from experiments I and II comparing two different dietary protein sources and three lysine levels[a]

	Dietary protein		Dietary lysine level %		
	C-SB-SM[a]	C-SB	.95	1.10	1.25
Average initial weight, kg[b]					
Experiment I	6.9	6.8	6.7	6.9	6.9
Experiment II	7.1	7.4	7.2	6.9	7.5
Average	7.0	7.1	6.9	6.9	7.2
Average daily gain, kg					
First 7 days					
Experiment I	.17	.18	.16	.17	.18
Experiment II	.22	.22	.19	.23	.23
Average	.19	.20	.17	.20	.20
28 days					
Experiment I	.44	.42	.41	.42	.45
Experiment II	.38	.37	.35	.39	.39
Average	.41	.40	.38	.41	.42
Average daily feed, kg					
First 7 days					
Experiment I	.33	.33	.33	.34	.31
Experiment II	.33	.38	.35	.36	.35
Average	.33	.35	.34	.35	.33

(Continued)

Table 3 continued

	Dietary protein		Dietary lysine level %		
	C-SB-SM[a]	C-SB	.95	1.10	1.25
28 days					
Experiment I	.69	.69	.69	.68	.70
Experiment II	.65	.69	.62	.72	.67
Average	.67	.69	.66	.70	.69
Average gain/feed					
First 7 days					
Experiment I	.507	.549	.487	.502	.594
Experiment II	.654	.588	.560	.635	.667
Average[c]	.572	.566	.519	.561	.626
28 days					
Experiment I	.632	.609	.604	.612	.645
Experiment II	.587	.540	.562	.541	.587
Average	.612	.578	.585	.580	.619

[a]C-SB-SM = corn-soybean meal-sesame meal. C-SB = corn-soybean meal.
[b]Each value is an average for five pens of six pigs each in Experiment I, four pens in Experiment II.
[c]Average gain/feed values among lysine levels differed ($P<.05$).

Table 4. Response of five-week-old pigs to different dietary proteins and lysine levels (Experiment III)

Protein source	Corn-soybean-sesame			Corn-soybean meal		
Dietary protein, %	20	20	20	18	20	20
Dietary lysine, %	.95	1.10	1.25	.95	1.10	1.25
Average initial weight, kg[a]	10.3	10.0	9.8	10.1	10.1	10.3
Average daily gain, kg						
First 7 days	.35	.38	.36	.39	.37	.37
28 days[b]	.47	.48	.44	.50	.44	.43
Average daily feed, kg						
First 7 days[b]	.61	.66	.62	.66	.53	.54
28 days[b]	.91	.89	.84	.93	.76	.73
Average gain/feed						
First 7 days	.580	.574	.584	.576	.710	.705
28 days[c]	.512	.538	.526	.543	.575	.586
Effect of protein source						
Average daily gain, kg						
First 7 days		.36			.38	
28 days		.46			.46	
Average daily feed, kg						
First 7 days		.63			.58	
28 days		.88			.81	
Average gain/feed						
First 7 days		.580			.664	
28 days[c]		.525			.568	

Table 4 continued

Protein source	Corn-soybean-sesame			Corn-soybean meal		
Dietary protein, %	20	20	20	18	20	20
Dietary lysine, %	.95	1.10	1.25	.95	1.10	1.25
Effect of lysine level						
Average daily gain, kg						
First 7 days				.37	.37	.36
28 days				.48	.46	.43
Average daily feed, kg						
First 7 days				.63	.59	.58
28 days				.92	.82	.78
Average gain/feed						
First 7 days				.578	.630	.644
28 days				.527	.556	.556

[a]Each value is an average for four pens of eight pigs each. The pigs were weaned at four weeks, started on experimental diets when five weeks of age.
[b]Diet by lysine interaction significant (P<.05).
[c]Average gain/feed value was greater (P<.01) for the corn-soybean meal diets than for the corn-soybean meal-sesame meal diets.

December, 1981 1981-5
University of Illinois at Urbana-Champaign
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Regulation of the Corpus Luteum in Swine

JANICE BAHR

The corpus luteum (CL) is an endocrine structure located on the ovary. It is formed by the cells which surround the egg prior to ovulation. The function of the CL is to produce a hormone, progesterone, which acts on the uterus to prepare a suitable environment for implantation of the fertilized egg and maintenance of pregnancy. If pregnancy does not occur, progesterone levels begin falling on day 14 of the cycle and the animal returns to heat on day 21. This drop in progesterone is the result of the CL no longer producing the hormone. If the sow or gilt becomes pregnant, progesterone levels do not decline at day 14 and no heat period is seen. If the animal is given progesterone, through the feed or by injection, no heat period is seen and no ovulation occurs (Brinkley et al., 1964). Three or four days prior to the onset of heat, 6 or 7 follicles per ovary begin a rapid development. Each follicle contains one egg which will ovulate 24-36 hours after the onset of heat (Buttle and Hancock, 1967). The cells of the recently ovulated follicles form a new group of CLs, progesterone increases, and the animal goes through another cycle. By controlling the CL, one can control the length of the cycle. Controlling the length of the estrous cycle has great practical implications for the swine industry.

Our approach to understanding the regulation of the corpus luteum was to measure the activity of the enzyme, adenylate cyclase (AC), which is located in the membrane. This enzyme is important because it mediates the action of trophic hormones on the corpus luteum. In other words, as long as this enzyme is active, the CL is functional and progesterone is produced by the CL. Therefore, measurement of this enzyme is one of the first steps in understanding the regulation of the CL.

Crossbred gilts (80-90 kg) were checked daily for heat for 2 consecutive estrous cycles. On the first day of estrus, day 0, blood samples were taken every other day until the next estrus. Ovaries were removed and CL tissue was collected on day 3, 8, 13, and 18. Membrane fractions from CL were prepared according to the procedure of Birnbaumer et al. (Endocrinology 99:163, 1976). Membranes were assayed for AC activity using optimal conditions established in our laboratory. The AC activity was measured with 10 μg/ml luteinizing hormone. We found that the AC enzyme system was active throughout the cycle with the highest activity measured on day 13 of the cycle. This date is of interest because the CL of the cycle is converted to the CL of pregnancy on day 13 of the cycle. However, the responsiveness to luteinizing hormone, the trophic hormone which stimulates the CL, was minimal which indicates that apparently the CL of the cycle dces not need LH support.

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December, 1981 1981-6

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Relative Efficacy of Glucose and Sucrose in Complex Pig Starter Diets

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INTRODUCTION

Sucrose, or ordinary table sugar, has been used extensively by the commercial feed industry to give a sweet flavor to pig starter diets. The volatile price of this commodity in recent years has led to the suggestion that consideration should be given to alternatives to sucrose. Dextrose or glucose monohydrate is a logical carbohydrate to consider. Dextrose can be prepared easily from cornstarch and is readily absorbed and metabolized by the pig. Hedonic preference tests conducted with human subjects generally rank dextrose only slightly below sucrose in sweetness.

It is clear from many reports (Lewis *et al.*, 1953; Jensen *et al.*, 1955; Hanson *et al.*, 1954 and Wahlstrom *et al.*, 1974) that the starter pig prefers sweet diets. Opinions differ regarding the value of sweeteners as a means of increasing intake and improving pig performance. Lewis *et al.* (1953) reported that starter pigs preferred diets containing 15% sucrose and that sugar in starter diets, whether pelleted or meal, significantly improved feed efficiency. Gain, however, was improved only in the case of the pelleted diet. Diaz *et al.* (1956) also found that sucrose either in a refined form or as unrefined cane sugar promoted improved feed consumption and weight gains by starter pigs. A large experiment at Iowa State involving eight trials, 1,112 pigs and both sucrose and saccharin (Aldinger *et al.*, 1961) did not show a performance response to sucrose. Wahlstrom *et al.* (1974) were unable to show a definite improvement in pig performance when sucrose was added to the diet; however, palatability trials clearly confirmed the pigs' preference for diets containing sucrose.

Sucrose has been compared to saccharin, an artificial sweetener, in several experiments. Jensen *et al.* (1955) found that starter pigs consumed nine times more of a 20% sucrose diet than of a diet containing .05% saccharin. Nonetheless, pigs prefer diets containing saccharin over diets without saccharin (Aldinger *et al.* 1959).

We have found only one published report (Bayley and Carlson, 1970) that deals with the use of glucose as a sweetener in starter diets. The addition of 5% glucose to a complex diet fed to weanling pigs failed to improve pig performance. It was apparent that additional research was needed with glucose (or dextrose as it is referred to in the commercial, hydrated form) in order to establish its value.

[1] The support of the A. E. Staley Co., Decatur, IL is gratefully acknowledged.

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The experiments described herein were conducted to determine if pig performance is affected by the substitution of dextrose or sucrose for equivalent amounts of cornstarch and to determine the level of dextrose and sucrose preferred by starter pigs.

EXPERIMENTAL PROCEDURES

Six experiments were conducted using 424 crossbred starter pigs. In each case the pigs were weaned at four weeks of age, moved to nursery pens and fed an unsweetened corn-soybean meal starter diet for a minimum of seven days before the experiments were initiated. This practice of starting the experiments one week post-weaning was adopted to avoid variation introduced by differential consumption patterns during the period of adjustment to dry feed.

The pigs were housed in 1.2 x 1.2 m pens equipped with solid partitions, slotted metal floors and automatic waterers. Temperatures were maintained well within the range of thermoneutrality and adequate ventilation was provided mechanically. The light period in the nursery was approximately equal to natural daylength.

Preference in experiments 2, 3 and 4 was measured using the single-stimulus method first described for swine by Aldinger and Fitzgerald (1966). With this procedure pigs were alternately given access to each of the two diets being tested. For example, diet A was placed in the pen for a four-hour period followed by a second four-hour period of access to diet B. During the third period the pigs were again given access to diet A. This feeding pattern was maintained from 0800 hours to 2400 hours daily. The feeder was not changed from 2400 hours to 0800 hours on the following day. This results in an odd number of four-hour periods in a 16-hour day with the net effect being alternate diets offered from 2400 to 0800 hours on successive days. An obvious limitation of the single stimulus method is that one is restricted to two comparisons at a time. This limitation is not severe although it does affect the design of experiments.

The basal diets employed in these experiments are presented in table 1. A randomized complete block design was used with blocks being formed on the basis of weight, sex and ancestry in each experiment.

Table 1. Composition of basal diets fed

		Basal Diet	
		A	B
Ingredient (%)	Exps.:	1,2,5	3,4,6
Ground corn		47.49	35.43
Soybean meal		20.74	22.75
Rolled oats		10.00	10.00
Fishmeal		5.00	5.00
Dried whey		5.00	5.00
Defluorinated rock phosphate		.57	.84
Limestone		.50	.28
Trace mineralized salt[1]		.35	.35
Illini vitamins[2]		.10	.10
Antibiotic		.25	.25
	Total	90.00	80.00

(Continued on next page)

[1]Provides per kg of complete diet: Se, .10 mg; I_2, .35 mg; Cu, 8.0 mg; Mn, 20 mg; Fe, 90 mg; Zn, 78 mg; Co, .75 mg; salt, 2.82 g.
[2]Provides per kg of complete diet: vitamin A, 3,300 IU; vitamin D_2, 330 IU; vitamin E, 22 IU; riboflavin, 1.10 mg; Ca-pantothenate, 6.6 mg; niacin, 16.5 mg; choline chloride, 165 mg; vitamin B_{12}, 17.6 mcg.

Experiment 1

One hundred twenty pigs were used in two identical trials with average initial weights of 8.06 and 5.09 kg in trails 1 and 2, respectively. The basal diet A (table 1) plus 10% cornstarch served as the control. The two experimental treatments were 2) basal + 10% sucrose (SUCROSE) and 3) basal + 10% Staley-Dex® (DEXTROSE). Pigs were allowed access to only one randomly assigned treatment diet for the entire 28-day experiment. Weight gain and feed intake were measured biweekly.

Experiment 2

Forty pigs with an average initial weight of 8.81 kg were allotted to eight pens by weight and sex. The basal diet A (table 1) + 10% sucrose (SUCROSE) was compared to basal diet A + 10% Staley-Dex® (DEXTROSE) using the single stimulus method described previously. Weight gain and feed intake were measured biweekly.

Experiments 3 and 4

Seventy-two pigs with average initial weights of 9.71 and 9.68 kg were used in Experiments 3 and 4, respectively. Basal diet B (table 1) + 20% cornstarch was used as the reference standard in both experiments. The four experimental diets were formed by replacing from 5 to 20% of the cornstarch in the reference standard diet with 5% increments of dextrose or sucrose in Experiments 3 and 4, respectively. Each experimental diet was compared to the reference standard diet using the single stimulus method described previously. Feed intake of all diets was determined at two-day intervals for the duration of the 28-day experiments. Weight gains were obtained weekly.

Experiment 5

Sixty pigs weighing 9.95 kg initially were used. Basal diet A (table 1) + 10% cornstarch was used as the reference standard diet. Control pens received fresh standard diet every three days after determining feed intake. Treatment groups received either basal diet A + 10% Staley-Dex® (DEXTROSE) or basal diet A + 10% sucrose (SUCROSE), for the first three-day period. Thereafter, the treatment groups were offered the reference standard diet and experimental diets alternately on three-day intervals. Feed intake was determined prior to every feed change and weight gain was measured every 12 days for the 36-day experiment.

Experiment 6

Sixty pigs with an average initial weight of 9.68 kg were used. Basal diet B (table 1) + 20% cornstarch served as the CONTROL. Treatments consisted of basal diet B + 10% Staley-Dex® (DEXTROSE) and basal diet B + 15% sucrose (SUCROSE). Cornstarch was added to the DEXTROSE and SUCROSE diets up to 100%. All groups were allowed access to their assigned treatment diet only. Feed intake was determined every three days and pig weights obtained every nine days during the 28-day experiment.

RESULTS AND DISCUSSION

The combined results for both trials in Experiment 1 are summarized in table 2. There was no difference ($P<.05$) in feed intake, daily gain or feed efficiency due to the 10% substitution of either sucrose or dextrose for cornstarch throughout the 28-day trials.

Table 2. Combined performance of pigs in trials 1 and 2, experiment 1

Criteria[a,b]	Diet CONTROL	DEXTROSE	SUCROSE
Avg. daily gain (kg)			
Day 1 to 14	.230	.232	.225
Day 14 to 28	.535	.540	.511
Day 1 to 28	.389	.392	.374
Avg. daily feed (kg)			
Day 1 to 14	.395	.403	.395
Day 14 to 28	.876	.931	.878
Day 1 to 28	.643	.675	.644
G/F ratio			
Day 1 to 14	.536	.554	.552
Day 14 to 28	.632	.598	.604
Day 1 to 28	.616	.590	.594

[a]Mean of four replicate pens with five pigs/pen.
[b]Treatment means are similar ($P<.05$) for all variables.

The preference of starter pigs for either dextrose (Staley-Dex®) or sucrose was investigated in Experiment 2 and the data was summarized in table 3. The pigs' preference for dextrose was evident during the first 14 days of the experiment but on a percentage basis was equivalently reversed in favor of sucrose during the second 14 days. This interaction of dietary preference with time was significant ($P<.001$) and unrelated to differences in caloric density of the diets caused by the different ME content of the two carbohydrates.

Table 3. Summary of feed intake for experiment 2

Criteria	Period:	Day 1 to 14		Day 14 to 28	
	Diets:	SUCROSE	DEXTROSE	SUCROSE	DEXTROSE
Feed intake[a,b] (kg/pen of 5 pigs)		25.77	33.21	44.20	34.09
% of total intake (within period)		43.70	56.30	56.50	43.50
Kcal ME/pig/day (calculated)		1182	1506	2028	1546

	SUCROSE	DEXTROSE
Overall feed intake (kg/pen of 5 pigs)	69.97	67.30

[a]Significant treatment x time interaction ($P<.001$)
[b]Values are the means of eight replicate pens with five pigs/pen.

The total feed intake and preference for each level of carbohydrate inclusion, indexed by experimental diet intake as a percent of total feed intake, for the entire 28-day test period of Experiments 3 and 4 is combined in table 4. This method of determining dietary preference clearly indicated that starter pigs, when given the choice, will consume more of a diet sweetened with either sucrose or dextrose than a comparable starch control diet. Pigs were also stimulated to consume more total feed when up to 10% sucrose or dextrose were substituted for cornstarch. The preference level also peaked at 10% for dextrose, but the preference for sucrose plateaued at 15%. The average daily gain (ADG) for the entire test period closely paralleled numerically the total feed intake response to each treatment level of the respective carbohydrate inclusion; however, treatment differences failed to be significant (P>.05).

Table 4. Summary of feed intake and daily gain for experiments 3 and 4

Criteria[a]	Carbohydrate Level 5%	10%	15%	20%	SEM
Total feed intake[b]					
DEXTROSE[e,f]	11.90	13.46	12.42	12.52	.221
SUCROSE[d,e]	11.37	12.27	11.89	12.44	.198
% preference[c]					
DEXTROSE[e]	57.1	65.9	64.6	59.3	1.063
SUCROSE[d]	61.4	61.7	65.1	64.0	.958
Avg. daily gain					
DEXTROSE	.505	.551	.533	.525	.039
SUCROSE	.484	.535	.513	.543	.029

[a]Each value is the treatment mean of three replicate pens with five pigs per pen.
[b]Combined feed intake (reference standard diet + sweetened diet) per two-day period per pen of five pigs.
[c]All are different than 50% (P<.05).
[d]Linear effect (P<.05).
[e]Quadratic effect (P<.05).
[f]Cubic effect (P<.05).

Attempting to obtain the same feed intake stimulation by switching from a starch control to sweetened diets on three-day intervals produced limited success as outlined in table 5. Obviously, as the pigs grew, daily feed requirements increased linearly. This is clearly demonstrated by the linear increase (P<.05) in three-day feed intake of those pigs fed the cornstarch CONTROL diet. When pigs were switched from the cornstarch CONTROL diet to either the DEXTROSE or SUCROSE test diets the increased three-day feed intake was greater than the corresponding successive switch back to the CONTROL diet. This indicated that sweetened diets were preferred by the pigs. However, the average three-day feed intake and ADG for the entire 36-day experiment were not different (P>.05) regardless of dietary treatment.

Table 5. Summary of feed intake for experiment 5

	Treatment						
	CONTROL		DEXTROSE		SUCROSE		Period
Period Diet:	CON[a]	CON	DEX[a]	CON	SUC[a]	CON	means
Day 1 to 3	8.87		8.73		9.45		9.02
Day 4 to 6		10.26		10.58		11.10	10.65
Day 7 to 9	12.53		12.09		13.14		12.59
Day 10 to 12		14.32		13.17		13.55	13.68
Day 13 to 15	15.85		15.66		16.87		16.13
Day 16 to 18		16.51		14.98		15.97	15.82
Day 19 to 21	17.86		18.74		19.22		18.61
Day 22 to 24		18.75		17.20		16.93	17.63
Day 25 to 27	17.67		17.34		17.48		17.49
Day 28 to 30		17.98		17.72		17.45	17.72
Day 31 to 33	19.86		19.91		18.61		19.46
Day 34 to 36		20.36		20.33		19.25	19.98
Diet $\bar{x}$	15.44	16.36	15.41	15.66	15.80	15.71	
Intake $\bar{x}$	15.90		15.54		15.75		
Avg. daily gain	.549		.525		.542		

[a]CON = CONTROL diet, DEX = DEXTROSE diet, SUC = SUCROSE diet..
[b]Each value is the mean three-day intake of three replicate pens expressed as kg of feed consumed per pen of five pigs.

Although performance was not improved by the inclusion of sucrose or dextrose in experiment 1, the results of subsequent experiments 3 and 4 suggested that both feed intake and daily gain could be stimulated by substituting the proper level of each carbohydrate for cornstarch. The results of experiment 6 (table 6) show that, when the preferred level of dextrose and sucrose (10 and 15%, respectively) are added to the diet, both feed intake and daily gain were improved. Adjustment of ADG and G/F ratios to a constant feed intake by covariance analysis eliminated differences due to treatment for both variables. Thus it was concluded that the improved ADG from the inclusion of either dextrose or sucrose was only a function of increased feed intake and that both carbohydrates were utilized at least as well as cornstarch.

Table 6. Summary of feed intake, daily gain and G/F ratios for experiment 6

	Diet		
Criteria[a]	CONTROL	DEXTROSE	SUCROSE
Avg. daily gain (kg)			
Overall[b]	.496	.558	.538
Adjusted for ADF	.518	.533	.541
Avg. daily feed (kg)			
Overall[b,c]	.855	1.006	.920
G/F ratios			
Overall[c]	.579	.555	.586
Adjusted for ADG	.569	.589	.600

[a]Mean of four replicate pens with five pigs/pen.
[b]CONTROL vs SUGAR (ie., dextrose and sucrose) is different (P<.05).
[c]DEXTROSE vs SUCROSE is different (P<.05).

The discrepancy between these results and those obtained in experiment 1 might be explained by the obvious poor growth and low feed intake of those pigs in experiment 1, particularly in the first 14 days. This may be a result of the combination of lower initial weights and younger physiological state.

CONCLUSION

The results of the experiments described herein indicated that starter pigs have a distinct preference, as determined by feed intake with the single stimulus methods, for diets sweetened with either dextrose or sucrose compared to a corn-starch control. However, it remains to be proven whether this response is due to the inclusion of the sugars or to a distaste for starch. When access is given to only one diet, the inclusion of 10% dextrose and to a lesser extent 15% sucrose increased daily gain and feed intake when compared to a starch control. This response was evident only when pigs were growing rapidly and consuming normal amounts of feed daily.

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December, 1981 1981-7

University of Illinois at Urbana-Champaign

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Response of Growing-Finishing (Weanling to Market) Pigs to Lactobacillus Acidophilus (Probios Brand)

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INTRODUCTION

Several research groups have assessed the efficacy of dried microbial preparations containing Lactobacillus Acidophilus in experiments that have yielded conflicting results. Pollman et al. (1980a) recently reported a nonsignificant ($P > .05$) numeric tendency toward improved gain when a Lactobacillus Acidophilus product (Probios®)[1] was added to the diet of starter pigs. However, Probios® had no effect on performance of growing-finishing pigs (Pollman et al., 1980b). These same workers had previously reported (Danielson, 1976) a lack of response to probiotic addition to starter pig diets. Similarly, two other experiments, one from Michigan State (Bebiak, 1979) and the other from Purdue (Cline et al., 1976) have found no advantage to the addition of Lactobacillus Acidophilus.

This experiment was designed to test the efficacy of Probios®, a product containing Lactobacillus Acidophilus when added to swine diets from weaning to market weight.

EXPERIMENTAL PROCEDURE

A total of 144 crossbred pigs were used in a randomized complete block design. There were six pen replicates of each treatment with six pigs per pen and constant proportion of barrows to gilts within pen and replicate. Replicates were formed on the basis of weight, sex and litter of origin.

Pigs were allotted based on weaning weight at approximately 28 days of age, then moved immediately into their assigned pen. Two days were allowed for social adjustment. Treatment diets were fed and initial weights determined on the third day post-weaning. There were no antibiotic or probiotic compounds in the sow's feed, the creep feed or the starter diet used during the two-day adjustment period. Pigs were housed in totally enclosed confinement buildings throughout the experiment. Elevated decks were used in the starter phase and the air temperature was maintained above 26C. The growing-finishing pens had solid concrete floors that were cleaned manually each day. Air temperature in the growing-finishing unit

[1]A product of Pioneer Hi-Bred International, Inc., Microbial Products Division, 3930 S.W. Macadam Ave., Portland, Oregon, 97201.

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was maintained at a level appropriate for the size of the pigs and wood shavings were used for bedding.

Control diets for each period of growth were formulated according to N.R.C. (1979) recommendations and are shown in table 1.

Table 1. Composition of control diets

Ingredient	Starter[a] 18%	Grower[a] 16%	Finisher[a] 13%
Ground corn	73.78	78.95	87.00
Soybean meal (48%)	23.70	18.80	11.05
Defluorinated phosphate	1.50	1.30	.90
Limestone	.57	.50	.60
TM salt[b]	.35	.35	.35
Illini vitamin mix[c]	.10	.10	.10
% Protein	18.0	16.0	13.0
% Calcium	.75	.65	.55
% Phosphorus	.60	.55	.45
% Lysine	.94	.80	.57

[a]Starter diets - 6-20 kg liveweight
Grower diets - 20-56 kg liveweight
Finisher diets - 56-94 kg liveweight
[b]Provides per kg of diet: Se, .10 mg; I_2, 35 mg; Cu, 7.70 mg; Mn, 20.0 mg; Fe, 90.0 mg; Zn, 77.9 mg; Co, .75 mg; salt, 2.82 g.
[c]Provides per kg of diet: vitamin A, 3300 IU; vitamin D_2, 330 IU; vitamin E, 22 IU; riboflavin 1.10 mg; Ca-pantothenate, 6.6 mg; niacin 16.50 mg; choline chloride, 165 mg; vitamin B_{12}, 17.6 mcg.

Pigs were allowed free access to self-feeders from weaning to market weight. The four experimental dietary treatments are described in table 2. All diets were prepared in 455 kg batches as needed. Storage time (mixing to consumption) rarely exceeded 10 days. All pigs were weighed bi-weekly. However, as they approached the weight designated for a diet change more frequent weighings were made as required. Diets were changed by replicate when the average pig weight within replicate reached the predesignated weight for each period of growth.

During the initial 21 days of the starter phase of the experiment, pigs were observed daily and the degree of fecal looseness was estimated. This score, or fecal consistency score, was estimated as follows:

1 = soft but formed stools
2 = soft with some texture, not formed
3 = very soft, little texture or form
4 = watery, no texture or form

Fecal score was multiplied by the number of pigs exhibiting the respective severity of scouring daily. Pen score was calculated by summing daily totals and dividing by the number of pig days.

Table 2. Experimental treatments

Treatment	Treatment Description
Control	18%, 16%, and 13% crude-protein corn-soy starter (weaning to 20 kg), grower (20 to 56 kg), finisher (56 kg to market weight) diets, respectively.
Probios®	As 1 + Lactobacillus Acidophilus (Probios® brand), 1 kg/1000 kg diet from weaning to 20 kg body weight, 500 grams/1000 kg diet to market weight.
Tylan®	As 1 + Tylosin, 22 grams/1000 kg diet from weaning to 56 kg, 11 grams/1000 kg diet from 56 kg to market weight.
CSP-250®	As 1 + 2.5 kg/1000 kg diet CSP-250 (110 grams chlortetracycline, 110 grams sulfathiazole and 55 grams penicillin) from weaning to market weight.[a]

[a]A 15-day withdrawal was observed before the pigs were actually marketed.

Performance data were statistically analyzed using the SAS computing package for a randomized complete block design. Treatment differences were determined using the F-protected least significant difference procedure.

RESULTS AND DISCUSSION

The summary of pig performance is shown in table 3. During the starter period (6 to 20 kg) both daily gain and gain:feed ratio were improved ($P<.05$) by CSP-250® but not Tylan® or Probios® . However, there was a numerical (15 and 11%), but nonsignificant ($P>.05$), improvement in gain and feed efficiency, respectively, with Tylan® addition whereas pigs fed Probios® had slower (7%) and less (8%) efficient gains during this period. Fecal consistency was improved ($P<.05$) by antibiotics but not by Probios®. During the grower period (20 to 56 kg) daily gain and feed intake were improved by CSP-250®. There was a numerical improvement similar to that observed in the starter period in gain and feed intake with Tylan® supplementation. From 56 kg to market weight, gain was enhanced ($P<.05$) by both Tylan® and CSP-250® and there was a slight but nonsignificant improvement elicited by feeding Probios® relative to the control. Statistically, the performance of pigs fed Probios® during the finisher period was not different from that of the pigs fed either antibiotic or the control diet.

CONCLUSIONS

The results of this experiment indicated that the improved weight gain observed by feeding either Tylan® or CSP-250® is primarily a result of better feed utilization during the starter period. However, their efficacy as growth promotants during the grower and finisher periods is principally an improved feed intake. Although there was a numeric advantage for CSP-250® versus Tylan® during the starter and grower periods, we were unable to detect a significant difference between the two antibiotics when compared over the entire experiment (weaning to market weight). Probios® brand probiotic was non-efficacious as a growth promotant, particularly in the critical starter period. These data are congruent with results observed by others in similar experiments involving Lactobacillus Acidophilus (Pollman et al., 1980; Danielson, 1976; Bebiak, 1979; and Cline et al., 1976).

Table 3. Effect of dietary additives on pig performance

Criteria[e]	Diet: Control	Probios®	Tylan®	CSP-250®	SEM
Starter period (6 to 20 kg)					
ADG, kg	.274[a]	.255[a]	.315[ab]	.354[b]	.023
ADF, kg	.614	.630	.641	.662	.030
G/F ratio	.443[ab]	.406[a]	.493[bc]	.534[c]	.023
Grower period (20 to 56 kg)					
ADG, kg	.631[a]	.633[a]	.680[ab]	.710[b]	.025
ADF, kg	1.380[a]	1.422[a]	1.524[ab]	1.741[b]	.073
G/F ratio	.462[a]	.447[a]	.447[a]	.408[b]	.011
Finisher period (56 to 94 kg)					
ADG, kg	.815[a]	.842[ab]	.899[b]	.910[b]	.025
ADF, kg	2.576	2.666	2.740	2.755	.078
G/F ratio	.317	.317	.330	.331	.011
Overall test (6 to 94 kg)					
ADG, kg	.583[a]	.589[a]	.636[b]	.655[b]	.015
ADF, kg	1.537[a]	1.588[ab]	1.627[ab]	1.690[b]	.037
G/F ratio	.380	.371	.391	.388	.008
Fecal score[d]	1.50	1.58	1.26	1.39	.099
Adj. days to 94 kg	157[a]	156[a]	147[b]	142[b]	2.8

[a,b,c] Means on the same line without a common superscript are different (P<.05) (Determined by FLSD test).
[d] Antibiotics decreased severity of scours (P<.05).
[e] All values are treatment means of six replicate pens with six pigs per pen.

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December, 1981 1981-8

University of Illinois at Urbana-Champaign

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Storage Stability of Frozen Pork Patties

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A major problem in frozen storage of pork products is the development of off-flavors due to oxidation of unsaturated fatty acids in the pork. Pork is more susceptible to oxidation than beef because of its higher content of polyunsaturated fatty acids. Ground pork is even more prone to lipid oxidation because disruption of muscle membranes exposes labile lipid components to oxygen and other catalysts. The objective of this study was to evaluate the effect of a commonly used ground pork seasoning in combination with vacuum packaging on the frozen storage stability of chilled and hot-processed ground pork.

Four replicates of two carcasses each were used in a 2x2x2 factorial experiment. Half of each carcass was stored at 4°C for 2 days then processed into pork patties and the other half was hot-deboned and processed immediately. Boneless shoulders and hams were chopped, the fat content adjusted to 25% and a commercial spice mix was added where appropriate. The chopped meat was ground and stuffed into oxygen-permeable or air impermeable packaging, chilled in an air blast freezer and sliced into patties. Two packaging methods were used after slicing; they were vacuum packaging and air permeable packaging. All packages were stored at -20°C until examined. At each sampling period (2,4,8,16,24 weeks of storage) patties were analyzed for TBA content, sensory evaluation, total bacterial plate count, and moisture cooking loss. Table I shows the least square estimate of TBA values at various storage periods. The results show that when seasoned samples were vacuum packaged the chilled processed products (CSV) had significantly higher TBA values than the hot processed samples (HSV); however, without seasoning and vacuum packaging the hot processed sample (HNP) had significantly higher TBA values than the chilled processed samples (CNP). This shows the significant interaction between processing and packaging methods and demonstrates the beneficial effect of hot processing when combined with vacuum packaging.

Taste panel evaluation further illustrated the storage stability of frozen pork patties. As a whole, hot processing had little effect on taste panel rancidity evaluation and as expected added seasoning during storage reduced the flavor scores significantly. Vacuum packaging significantly improved the flavor of seasoned products. Bacterial counts were not significantly different among treatments throughout the 24 weeks of frozen storage. The effect of hot processing on cooking loss was measured. Chilled processed patties had significantly lower moisture cooking losses than did hot processed patties, particularly when no seasoning was added. As expected, the addition of seasoning (80% salt) decreased the moisture cooking loss.

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Table 1. Least square estimate of TBA values

	Storage Time					
Treatment	2 weeks	4 weeks	8 weeks	16 weeks	24 weeks	AVG Std Error
HSV	.54	.19	.62	.67	.69	
					}	.03
CSV	.67	.71	.75	.80	.82	
HSP & CSP	.38	1.19	2.85	3.02	3.35	.07
HNV & CNV	.38	.48	.53	.54	.53	.03
HNP	.43	.54	.65	.76	.83	
					}	.03
CNP	.36	.47	.58	.69	.75	

H = Hot processing
S = Inclusion of seasoning during storage
V = Vacuum packaging
C = Chilled processing
N = Nonseasoned during storage (Seasoned prior to testing)
P = Air permeable packaging

In conclusion, the addition of a high salt seasoning, as expected, greatly enhanced lipid oxidation and this oxidation was markedly inhibited by the use of vacuum packaging. The results also demonstrated the interaction of processing method and packaging method and showed that with proper packaging methods, hot processing reduced lipid oxidation, particularly in ground pork seasoned with a commonly used spice mixture.

December, 1981 1981-9

University of Illinois at Urbana-Champaign

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Dietary Protein-Calorie Ratios for Young Pigs

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The potential for use of high-oil seeds in swine diets emphasizes the need to establish optimum dietary protein:calorie ratios (grams of protein per Mcal[1] of digestible energy). For example, plant geneticists have developed corns that contain 7 to 9% oil, which is markedly higher than the 3.5% in commercially-produced hybrids. The protein and lysine contents of these high-oil corns are not increased proportionally to the increase in oil, thus substituting these corns for regular corn in a pig's diet may result in inadequate protein (amino acids) relative to energy content. The National Research Council (NRC, 1979) recommends 57 grams of protein per Mcal of digestible energy (DE).

The objective of these experiments was to evaluate diets with ratios of protein:Mcal DE ranging from 53 to 71. Corn oil was used as the source of additional energy to fortified corn-soybean meal diets.

METHODOLOGY

Three-hundred and sixty crossbred pigs weaned at four weeks of age were used in two experiments. Average initial weight was about 6.0 kg. Pigs were allocated to dietary treatments on the basis of initial weight (at weaning), litter and sex. They were housed in a totally slotted floor nursery, and temperature was kept at 25°C during the first week, then progressively decreased 2°C per week until 20°C. Feed intake and weight change were recorded weekly.

Data were analyzed as a randomized complete block (RCB) in a factorial arrangement of treatments (Steel and Torrie, 1960) in Experiment 1, and as a RCB using the statistical analysis system (SAS, 1979) guidelines for the General Linear Model procedure in Experiment 2.

Experiment 1

Diets were formulated to contain either 20 or 24% crude protein and either 3.4, 3.6 or 3.8 Mcal DE/kg of diet[2]. These rations thus provided protein-calorie ratios of 53 to 71 (table 1). In all diets the recommended levels (NRC, 1979) for amino acids, vitamins and minerals were exceeded. Corn to soybean meal ratios were

[1] Mcal = megacalories = 1,000,000 calories.
[2] Data from this Experiment reported by Aherne and Jensen (1981).

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adjusted to permit the inclusion of corn oil to provide the different protein-calorie ratios. The feeding period was five weeks.

Experiment 2

In Experiment 1 a "complex" formula was used (table 1) and the corn-soybean meal ratios were changed to allow inclusion of corn oil to provide the desired Mcal DE/kg of diet. In Experiment 2, a 20% crude protein corn-soybean meal diet served as a standard of comparison (table 2). In the other diets the corn-soybean meal ratio remained constant to ensure the same amino acid profile. A linear increase of corn oil, as a percent of the diet, in replacement of cornstarch provided the desired protein-calorie ratios, which ranged from 61 to 53. The feeding period was for four weeks.

RESULTS AND DISCUSSION

The results of Experiment 1 are summarized in table 3. Within each dietary protein level (20 or 24%) both rate of gain (ADG) and daily feed intake (ADF) tended to decrease as diet energy increased. However, average gain/feed (G/F) value at each protein level was highest at the highest energy level. Comparing dietary protein effect, there were no significant differences between the 20 and 24% levels, although gain, gain/feed and gain/DE values were higher at the higher protein level.

Comparing energy levels, ADG (nonsignificantly) and ADF (significantly, $P<.005$) decreased as levels of energy increased, and G/F was highest at the highest energy level. However, gain/DE consumed did not appear to improve with increase in diet DE values.

In Experiment 2 (table 4) ADG was significantly ($P<.01$) affected by dietary treatment during the first two weeks. During this time when the increase in diet energy content resulted in a decrease ($P<.01$) in ADF, absolute intake of other nutrients (eg., amino acids) may have been inadequate, resulting in worsening feed efficiency. Over the 28-day period only ADF was significantly ($P<.01$) affected by dietary treatment. Pigs on the control diet (lowest DE content) consumed more than pigs on diets with higher DE contents. Average G/F during the second 14-day period differed ($P<.01$) among treatments, the control diet being lower ($P<.005$) than the other diets. For the 28-day period differences among diets were not statistically significant. However, G/F and G/Mcal DE values were highest with the diet containing 3.43 Mcal DE/kg. This was in agreement with Experiment 1 when G/Mcal DE on the 20% crude protein diet was not improved by increasing DE above 3.4 Mcal/kg of diet, equivalent to a protein:calorie ratio of 57.

SUMMARY

Two experiments were conducted to evaluate dietary protein:calorie ratios (grams of protein per Mcal of digestible energy) for pigs weaned at four weeks of age. The pigs averaged about 6.0 kg at weaning and were on test for 28 days. Protein:calorie ratios varied from 53 to 71.

In Experiment 1 diets contained 20 or 24% crude protein, and 3.4, 3.6 or 3.8 Mcal DE/kg. In Experiment 2 the diets contained 20% crude protein and either 3.27, 3.32, 3.43, 3.53, 3.64 or 3.75 Mcal DE/kg, providing, respectively, protein: calorie ratios of 61 to 53.

In both experiments daily gain and daily feed tended to decrease and gain/feed increase with increase in energy increase. On the 20% crude protein diets DE values above 3.4 Mcal/kg did not improve efficiency of performance.

Pigs fed the 24% crude protein diets had nonsignificantly higher rates of gain and gain/feed values than those fed 20% crude protein diets. Within the 24% diets highest rate of gain and gain/feed values were by pigs fed the 3.4 Mcal DE diets. Gain/ Mcal DE values, however, were similar on the 3.4 and 3.8 Mcal DE diets.

These results support the NRC recommendation of about 57 grams of protein per Mcal DE when the diet contains 20% crude protein. The effects of different dietary protein levels need further investigation.

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Table 1. Dietary treatments (Experiment 1)

Diet[a]	1	2	3	4	5	6
Ground corn	56.5	50.0	43.7	43.8	37.4	31.0
Soybean meal	23.1	24.3	25.5	34.1	35.3	36.5
Fish meal	5.0	5.0	5.0	5.0	5.0	5.0
Dried whey	10.0	10.0	10.0	10.0	10.0	10.0
Corn oil	3.0	8.3	13.4	4.7	9.9	15.1
Dical. phosph.	1.0	1.0	1.0	1.0	1.0	1.0
Ground limestone	0.6	0.6	0.6	0.6	0.6	0.6
Trace min. salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin mix	0.20	0.20	0.20	0.20	0.20	0.20
ASP·250	0.25	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 1 continued on next page

Table 1 Continued

Diet[a]	1	2	3	4	5	6
Calculated composition						
C.P., %	20.0	20.0	20.0	24.0	24.0	24.0
DE, Mcal/kg	3.40	3.60	3.80	3.40	3.60	3.80
Lysine, %	1.19	1.21	1.23	1.50	1.51	1.53
g Prot/Mcal DE	59	56	53	71	67	63

[a]As fed.

Table 2. Dietary treatments (Experiment 2)

Diet, %[a]	1 (Reference) Corn-SBM	2 Basal*
Ground corn	86.64	54.00
Soybean meal	28.38	31.02
Cornstarch	--	12.00
Corn oil	--	--
Def. rock phosphate	2.18	2.18
Trace min. salt	.35	.35
Vitamin mix	.20	.20
ASP-250	.25	.25
Total	100.00	100.00
CP, %	19.95	19.95
DE, Mcal/kg	3.27	3.32
Lysine, %	1.06	1.12
g Prot/Mcal DE	61	60

*In treatments 3, 4, 5 and 6 cornstarch was replaced by 3, 6, 9 and 12% corn oil, respectively; calculated energy content in cal/kg was: 3.43, 3.53, 3.64 and 3.25, respectively.
[a]As fed.

Table 3. Summary of effect of dietary protein and calorie levels on performance of weaned pigs (Experiment 1)

Dietary crude protein, %	20	20	20	24	24	24
Dietary DE, Mcal/kg[a]	3.40	3.60	3.80	3.40	3.60	3.80
Grams protein/Mcal DE	59	56	53	71	67	63
Avg. daily gain, kg[b]	.40	.41	.38	.44	.42	.40
Avg. daily feed, kg[c,d]	.65	.65	.56	.68	.64	.54
Avg. gain/feed	.61	.63	.67	.66	.65	.73
Avg. gain/Mcal DE, kg	.181	.175	.178	.190	.182	.195

Crude protein effect	20	24
Avg. daily gain, kg	.40	.42
Avg. daily feed, kg	.62	.62
Avg. gain/feed	.65	.68
Avg. gain/Mcal DE, kg	.177	.189

Energy level effect	3.40	3.60	3.80
Avg. daily gain, kg	.42	.41	.39
Avg. daily feed, kg	.66	.64	.55
Avg. gain/feed	.64	.64	.70
Avg. gain/Mcal DE, kg	.186	.177	.187

[a] Mcal = megacalorie = 1,000,000 calories.
[b] Each value is an average for four pens of six pigs each.
[c] Linear effect significant (P<.005).
[d] Quadratic effect significant (P<.025).

Table 4. Summary of effect of diet calorie density on performance of weaned pigs (Experiment 2)

Dietary crude protein, %	20	20	20	20	20	20
Dietary DE Mcal/kg	3.27	3.32	3.43	3.53	3.64	3.75
Grams protein/Mcal DE	61	60	58	57	55	53
Avg. daily gain, kg[a]						
First 14 days[b]	.17	.16	.10	.13	.11	.08
Second 14 days	.46	.46	.44	.43	.45	.42
Average	.32	.31	.27	.28	.28	.25
Avg. daily feed, kg						
First 14 days	.37	.32	.28	.31	.25	.27
Second 14 days[c]	.75	.69	.55	.55	.62	.56
Average[d]	.56	.50	.41	.43	.43	.41
Avg. gain/feed						
First 14 days	.47	.50	.35	.41	.51	.31
Second 14 days[c]	.62	.68	.82	.77	.71	.75
Average	.57	.62	.66	.64	.64	.60

Table 4 continued on next page

Table 4 Continued

	20	20	20	20	20	20
Avg. gain/Mcal DE, kg	.175	.187	.192	.184	.179	.163

[a]Each value is an average for four pens of four pigs each.
[b]Linear effect significant (P<.03).
[c]Significantly different among dietary treatments (P<.05).
[d]Significantly different among dietary treatments (P<.01).

December, 1981 1981-10

University of Illinois at Urbana-Champaign

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Possible Role of Liver Enzyme Level and Reproductive Formation

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The rate of detoxification of xenobiotics such as pesticides, herbicides, barbiturates, heavy metals and steroids is influenced by the level of activity of the mixed function oxidase (MFO) enzymes in the liver. The level of MFO can be raised by high levels of protein in the diet and by an increased plane of nutrition. As the level of MFO is raised the level of steroids is depressed. The negative feedback to the pituitary and the hypothalamus by the steroid is reduced with a resultant increase in gonadotropins. The gonadotropins such as follicle stimulating hormone (FSH) and luteinizing hormone (LH) are responsible for the growth of follicles and number of eggs ovulated. Steroids are necessary for maintenance of pregnancy. This may explain the basis for the recommendation to feed at a high plane before breeding and to reduce the level of feeding after breeding. With this hypothesis in mind, we measured the level of hormones in blood of cyclic gilts, pregnant gilts, gilts given steroids orally, barrows and castrated gilts with steroid implants or with gonads transplanted to the intestines and following variable protein levels in the diet. Feeding of barbiturates appears to influence ovulation rate. Low protein diets are associated with a low rate of disappearance of steroids. Orally administered steroids are very effectively taken out of the systemic circulation by the liver. Gonads transplanted to the intestines hypertrophy. These observations tend to support the idea that MFO level can be manipulated by diet and other treatments and that the effect can be reflected in the function of the reproductive system. The implications for the future are that reproductive efficiency in swine may be enhanced and controlled by proper manipulation of diet and other external factors when the basis for such action is understood.

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December, 1981 1981-11

University of Illinois at Urbana-Champaign

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Cottonseed Meal, Peanut Meal, and Fish Meal as Alternatives to Soybean Meal in Corn-Based Diets for Finishing Swine

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Soybean meal is the plant source of supplemental protein (amino acids) most frequently and extensively used in corn-based diets for swine. This is due to (1) the excellent amino acid profile of soybean meal, especially high lysine and tryptophan for supplementing the low-lysine, low-tryptophan protein in hybrid corn and (2) its economically competitive position. But in certain countries, especially those in tropical regions, other protein sources such as fish meal, cottonseed meal and peanut meal are often more readily available and frequently less expensive. Effective nutritional use of these, singly or in combination, could decrease feed costs in swine production. Cottonseed (CSM) and peanut meal (PM) are deficient in lysine compared to soybean meal (SBM), and biological availability of lysine from differently processed CSM's may vary (Knabe et al., 1979). CSM may also contain deleterious levels of gossypol (Watts, 1970; Albrecht et al., 1973; Smith, 1973). But processing technique can essentially eliminate the gossypol, and appropriate iron addition can render gossypol nontoxic to swine (Clawson and Smith, 1966; Knabe et al., 1979). Lysine supplementation of CSM and PM frequently makes them nutritionally comparable to SBM in diets for finishing swine. Fish meal (FM) is high in lysine and could be a good "natural source" of lysine to supplement the lysine-deficient CSM and PM. Also, in certain countries "high-lysine" corn (Opaque-2) is available and potentially could result in reduced need for supplemental proteins. This study was conducted to evaluate the use of CSM and PM, each without and with supplemental lysine (crystalline or from FM) and FM as replacements for SBM in hybrid corn- or Opaque-2 corn-based diets for finishing swine.

EXPERIMENTAL PROCEDURE

Four experiments involving 105 individually fed pigs were conducted. Except for the periods 0800 to 0930 and 1500 to 1630 hours when they were confined to individual stalls, the pigs were in groups of six to 10 in concrete-floor pens, with one automatic waterer per pen. While in the individual stalls the pigs had continuous access to feed. The feed was moistened to encourage consumption. The pigs were randomly assigned to dietary treatment from outcome groups based on weight. Body weight gain and feed consumption were determined weekly. Fortified corn-SBM or Opaque-2-SBM diets were used as control diets, composition of which is shown in tables 1 and 2. Crystalline lysine was added to CSM and PM diets to provide dietary levels similar to those of the control diets. When FM was used as the source of supplemental lysine, the biological availability was assumed to be 70%, probably a conservative estimate (Meade, 1972).

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Experiment I

This was designed to compare CSM and PM, each supplemented with either crystalline lysine or FM-lysine and FM with SBM as supplemental protein to hybrid corn in diets for finishing swine. An additional treatment was the corn-SBM diet with 1.7% cellulose to determine whether dietary fiber would affect performance, since CSM and PM have more crude fiber than does SBM or FM. The CSM was from the prepress solvent-extraction process and contained .05% free gossypol, 41% crude protein and 1.76% lysine. Thirty-five pigs averaging 55 kg in weight were used.

Experiment II

Experiment II was conducted to determine whether the relatively poor peformance for the pigs fed the corn-FM diet in Experiment I could be improved with addition of tryptophan. The report of Becker _et al_. (1966) indicated that this could be the first-limiting amino acid in a corn-FM diet for finishing pigs. Six pigs averaging 61 kg were used.

Experiment III

In Experiments III and IV the CSM was from a different source than that for Experiment I. It was from the direct solvent-extraction process and contained .3% free gossypol. Thus the dietary level of free gossypol was .039%, compared to .0075% in Experiment I. Also, Opaque-2 corn (Op) was used, and it contains higher levels of lysine and tryptophan than does regular corn. Thus, less supplemental protein is needed than with regular corn (Cromwell _et al_., 1967; Jensen _et al_., 1969). In Experiment III the Op-SBM diet had levels of .64% lysine, .25% methionine and .15% tryptophan, which levels exceed the NRC (1979) suggested requirements for the finishing pig. Lysine and methionine were added to the CSM and PM diets to provide levels similar to those in the Op-SBM diet. The 12.1% crude protein Op-FM diet contained .68% lysine, and tryptophan was added to equate that in the control diet.

Because of the higher gossypol level in the CSM, finely ground ferrous sulfate was added as a detoxicant to two of the Op-SBM diets. Twenty-eight pigs averaging about 51 kg were fed for 50 days.

Experiment IV

The results of Experiment III indicated that the iron supplementation to the Op-CSM diet completely overcame the apparent gossypol effect. Thus, in Experiment IV ferrous sulfate was added to the Op-CSM diet to provide 390 ppm of iron, which gave an iron:gossypol ratio of 1:1. Clawson (1966) and Rincon (1976) had reported that ratios of .5:1 to 1:1 prevented evidence of gossypol activity. Thirty-six pigs averaging 55 kg were on test until about 93 kg.

RESULTS

Experiment I

Pigs fed the corn-CSM diet with supplemental crystalline lysine gained .60 kg per day, which was significantly (P<.01) below that of all other pigs except those fed the corn-FM diet (table 3). Gain/feed was lower (P<.01) than for all other diets. This reduced performance should not have been due to the dietary-free gossypol level (.0075%) since apparently levels above .01% are necessary to produce toxicity (Hale and Lyman, 1957; Clawson *et al*., 1961). Nor would the dietary fiber level seem a cause since the 1.7% cellulose addition to the corn-SBM diet had no deleterious effect.

Inclusion of FM at the level of 4% in the corn-CSM diet improved (P<.01) pig performance over that from the crystalline lysine-supplemented diet.

The corn-PM diet plus crystalline lysine or FM produced gain and feed efficiencies similar to those of the corn-SBM diet. The pigs fed the corn-FM diet had the lowest daily feed intake.

Experiment II

The significant increase in daily gain (P<.01) and daily feed (P<.05) in response to tryptophan supplementation strongly suggested that the corn-FM diet in Experiment I was deficient, marginally at least, in tryptophan (table 4). Gain/feed was not signficantly affected.

Experiment III

Average daily gain and gain/feed of the pigs fed the Op-CSM diets were lower (P<.01) than for the pigs fed the Op-SBM, Op-PM and Op-FM diets (table 5). Daily feed intake of the Op-CSM diet without iron supplementation was less (P<.01) than that of any of the other diets. Within the Op-CSM dietary treatments the lowest rate of gain and feed intake (P<.01) were by the pigs fed the diet without iron supplementation. This would suggest a possible gossypol effect. The level of iron used (.25 iron:1 gossypol) in the other two Op-CSM diets was apparently insufficient to completely overcome the gossypol effect since rate of gain and gain/feed were below those of the pigs fed diets supplemented with SBM, PM or FM.

Performance of the pigs fed the Op-PM and Op-FM diets was comparable to that of pigs fed the Op-SBM diet.

Experiment IV

Performance was excellent in all groups, with no significant differences in any criterion among the dietary treatments (table 6). These data indicate that the supplemental levels of either crystalline lysine or FM-lysine used made the CSM and PM diets comparable to the SBM diet for pigs fed from 55 kg to slaughter weight (95 kg). The 390 ppm of ferrous sulfate iron added to the CSM diets was presumably effective since there were no toxicity symptoms.

SUMMARY

The results from these experiments indicate that correcting the lysine inadequacy of either cottonseed meal or peanut meal and the tryptophan deficiency of fish meal makes them viable substitutes for soybean meal in corn-based (regular hybrid or Opaque-2) diets for finishing pigs. Either synthetic lysine or fish

meal lysine was satisfactory for correcting the lysine deficiencies of cottonseed meal and peanut meal diets

The gossypol associated with cottonseed meal can be dealt with by processing method or by appropriate iron supplementation to the diet. Prepress solvent-extract CSM is low in free gossypol (.05% in Experiment I), which level has not been deleterious to finishing swine. However, the prepress treatment could possibly adversely affect protein quality. Solvent-extracted cottonseed meal, Experiments II through IV, contained .3% free gossypol. Supplemental iron (1:1 ratio of elemental iron to gossypol) was an effective detoxicant.

Table 1. Composition of basal diets, Experiments I and II

Supplemental protein	Soybean meal	Cottonseed meal	Peanut meal	Fish meal
	%	%	%	%
Ground yellow corn	80.30	82.62	83.49	90.15
Soybean meal[a]	13.50	--	--	--
Cottonseed meal[b]	--	15.00	--	--
Peanut meal[c]	--	--	14.00	--
Fish meal[d]	--	--	--	8.75
Defluorinated rock phosphate	1.25	1.23	1.70	.45
Calcium carbonate	.50	.55	.18	.20
Trace mineralized salt[e]	.35	.35	.35	.35
Vitamin mix[f]	.10	.10	.10	.10
Lysine-HCl[g]	--	.15	.18	--
Total	100.00	100.00	100.00	100.00
Calculated, %				
Crude protein	13.90	13.40	13.60	13.30
Lysine	.60	.58	.59	.62
Tryptophan	.16	.14	.14	.14
Crude fiber	2.84	4.19	4.24	2.70

[a] Solvent-extracted soybean meal. Assumed to contain 48.5% crude protein and 3% lysine.

[b] In Experiment I, prepress solvent extracted, contained .05% free gossypol, 41% crude protein and 1.76% lysine (Delta Products Co., Evadale, AK). In Experiments II to IV, CSM was solvent extracted. It contained about .3% free gossypol and 1.76% lysine (Osceola Products Co., Osceola, AK).

[c] Contained 45% crude protein and 1.6% lysine.

[d] Assumed to contain 61% crude protein and 4.7% lysine.

[e] Contained 1% Zn, .5% Fe, .1% Cu, .01% I, .01% Co, .8% Mn, .003% Se, 94% salt.

[f] Contained 1100 mg riboflavin, 5.5 gm calcium pantothenate, 110 mg choline chloride, 16.5 gm niacin, 17.5 mg vitamin B_{12}, 22,000 IU vitamin E, 3.3 million IU vitamin A and 330,000 IU vitamin D_2 per kilogram of premix.

[g] L-lysine monohydrocholoride (78% L-lysine activity).

Table 2. Composition of basal diets, Experiments III and IV

Supplemental protein	Soybean meal	Cottonseed meal	Peanut meal	Fish meal
	%	%	%	%
Opaque-2 corn[a]	86.20	84.53	85.47	90.65
Soybean meal[b]	11.50	--	--	--
Cottonseed meal[c]	--	13.00	--	--
Peanut meal[d]	--	--	12.00	--
Fish meal[e]	--	--	--	8.00
Defluorinated rock phosphate[f]	1.60	1.30	1.50	.70
Calcium carbonate	.25	.55	.35	.10
Trace mineralized salt[g]	.35	.35	.35	.35
Vitamix mix[h]	.10	.10	.10	.10
Lysine[i]	--	.14	.18	--
DL-methionine[j]	--	.03	.05	--
L-tryptophan[j]	--	--	--	.10
Total	100.00	100.00	100.00	100.00
Calculated				
Crude protein, %	12.5	12.6	11.9	12.1
Lysine	.64	.62	.61	.68
Tryptophan	.15	.15	.15	.15

[a]Contained 8% crude protein, .35% lsyine.
[b]Contained 48.5% crude protein and 3% lysine.
[c-i]See footnotes b-j table 1.
[j]Added to ensure dietary levels to meet requirements of the finishing pig.

Table 3. Summary of comparisons of soybean meal, cottonseed meal, peanut meal and fish meal as supplements to hybrid corn for finishing pigs (Experiment I)

	Supplemental protein						
	SBM		CSM[a]		PM		FM
Cellulose, %	--	1.7[b]	--	--	--	--	--
L-lysine added, %	--	--	.12	--	.14	--	--
Lysine from FM, %[c]	--	--	--	.18	--	.19	.39
Avg. daily gain, kg[d]	.71[ef]	.78[ef]	.60[g]	.71[ef]	.71[ef]	.82[e]	.64[fg]
Avg. daily feed, kg	2.75	2.67	2.62	2.70	2.60	2.72	2.39
Gain/feed	.28[f]	.29[f]	.23[g]	.26[h]	.27[f]	.30[f]	.27[f]

[a]Contained .05% free gossypol.
[b]This added level gave a dietary fiber level equivalent to that in the diets containing CSM or PM.
[c]The lysine in FM was assumed to have a biological value of 70%.
[d]Each value is an average for five individually fed pigs, initial weight, 55 kg.
[e-g]Values on the same line with different superscripts differ (P<.01).

Table 4. *Summary of results from supplementing the corn: fish meal diet with tryptophan (Experiment II)*

Added tryptophan, %	0	.05	.10
Avg. daily gain, kg[a,b]	.62[c]	.77[d]	.80[d]
Avg. daily feed, kg	2.32[c]	3.01[d]	2.94[d]
Gain/feed	.27	.26	.27

[a]Each value is an average for two pigs individually fed, average initial weight, 61 kg. Average final weight was 80 kg.
[b]Values were adjusted to initial weight.
[cd]Values on the same line with different superscripts differ ($P<.01$).

Table 5. *Summary of comparisons of supplements to Opaque-2 corn in diets for finishing pigs (Experiment III)*

	Supplemental protein						
	SBM	CSM[a]			PM[a]		FM
L-lysine added, %	--	.10	.10	--	.13	--	--
L-lysine from FM, %	--	--	--	.18	--	.23	.38
L-tryptophan added, %	--	--	--	--	--	--	.10
Ferrous sulfate added, %[b]	--	--	.05	.04	--	--	--
Avg. daily gain, kg[c]	.78[d]	.54[e]	.63[e]	.59[e]	.77[d]	.73[d]	.78[d]
Avg. daily feed, kg	2.33[d]	1.95[e]	2.33[d]	2.24[d]	2.40[d]	2.28[d]	2.30[d]
Gain/feed	.33[d]	.27[e]	.27[e]	.26[e]	.32[d]	.32[d]	.34[d]

[a]DL-methionine was added to the CSM (.03%) and PM (.05%) diets to equate the calculated dietary values with that in the Op:SBM diet.
[b]$FeSO_4 \cdot 7H_2O$.
[c]Each value is an average for 4 pigs individually fed, average initial weight about 51 kg. Final weight was about 90 kg.
[de]Values on the same line having different superscripts differ ($P<.01$).

Table 6. Summary of comparison of SBM, CSM plus lysine and iron, PM plus lysine and FM plus tryptophan as supplements to Opaque-2 corn in diets for finishing pigs (Experiment IV)

	Supplemental protein					
	SBM	CSM[a]		PM[a]		FM
L-lysine added, %	--	.10	--	.13	--	--
Lysine from FM, %	--	--	.18	--	.23	.38
L-tryptophan added, %	--	--	--	--	--	.10
Ferrous sulfate, %[b]	--	.20	.17	--	--	--
Avg. daily gain, kg[c,d]	.82	.76	.78	.82	.82	.79
Avg. daily feed, kg	2.52	2.42	2.42	2.56	2.46	2.43
Gain/feed	.33	.32	.32	.32	.33	.33

[a]See footnote, table 5.
[b]Provided a supplemental iron to free-gossypol ratio of 1:1.
[c]Each value is an average for six individually fed pigs, average initial weight of about 55 kg, final weight about 93 kg.
[d]There were no significant differences among dietary treatments for any criterion measured.

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December, 1981 1981-12

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A Comparison of Flooring Materials in Farrowing Crates[1]

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The use of slotted floors in swine housing usually results in elimination of bedding materials. The absence of bedding has apparently resulted in more frequent and severe injuries to feet and legs, especially to nursing piglets. Very little controlled experimentation relative to evaluation of different floor materials for farrowing crates has been conducted in the U.S. Hubly et al. (1974) reported that the direction-of-lie of expanded metal (across the rear 24 inches and the front 12 inches of the farrowing crate floor, wood inbetween) affected frequency and intensity of feet and leg injury of nursing piglets. Steel slats, 3-inches wide spaced at 3/8 inch, in the rear portion of the crate floor produced similar injuries as the expanded metal. However, in these comparisons the abrasions had no significant effect on piglet performance. Bartelson (1981) reported on a comparison of expanded metal, perforated stainless steel, round-rod grate, 1-inch galvanized flat steel spaced at 3/8 inch, 5 5/8-inch-wide perforated plastic slats spaced at 3/8 inch, and 1 11/16-inch-wide aluminum slats spaced at 3/8 inch. These various materials were used over the front gutter (12 inches wide) and the rear gutter (30 inches wide) of the crate floor, the center solid concrete being embedded with electric heating elements. The expanded metal ranked significantly higher than the other materials for cleanliness of pigs and pens.

Penny et al. (1978) surveyed many swine production units in England and observed that lesions such as abrasions and injury to feet, hocks, knees and teats were commonplace and were suspected as areas for bacterial infection. Smith (1976) reported a study in which 25% of the pigs observed had injuries to the front feet, 75% to the hind feet. He further stated that the most common sequel to erosion of claws or accessory digits was chronic bacterial infection, some of which would be indicated by septic arthritis. Up to 10% of pigs could be so affected. And the splayleg condition can presumably be seriously exaggerated by floor conditions (Kohler et al., 1969).

A NHF report (1980) cites Scottish researchers contending that the response of pigs to floors and the incidence of injury and disease "may be as much due to stocking density, litter size, temperament of the sow, or other biological factors as due to the structural properties of the floor". They rate expanded metal as undesirable for entire flooring for farrowing pens with piglets less than 14 days of age.

The study reported here was initiated to compare farrowing unit floors of different materials and designs. Performance and frequency and severity of feet and leg lesions on sows and piglets were bases of comparison.

[1]Assistance of Tom Park and Bob Gilbert in preparation and maintenance of floors is gratefully acknowledged.

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EXPERIMENTAL PROCEDURES

A 15-crate farrowing unit was modified to have three farrowing crates on each of five different floor arrangements:

1. Plastic-covered expanded metal (TENDERFOOT) for the entire 5 feet by 7 feet stall area. The solid metal plate in the front portion is to protect the floor covering from chewing or tearing by the sow (Figure 1).

2. Combination of wood (penta-treated 2-inch by 6-inch pine boards) and expanded metal (No. 9-11, flattened, 3/4 inch), which spanned the front 10 inches and rear 24 inches of the stall floor. Diamond-shaped opening in the expanded metal is parallel to the length of the stall (Figure 2).

3. Precast concrete section 5 feet by 7 feet. Rear portion has 1-inch slots 30 inches long. These were filled with iron bars during and for 24 hours after farrowing. The slots in the front portion are 1/2 inch by 18 inches (Figure 3).

4. Combination of plastic-covered metal (TENDERFOOT) and wood. Front and rear sections each 24 inches wide (Figure 4).

5. Combination of steel slats and wood. The slats are 1 inch wide and spaced at 1/2 inch, the section being 24 inches wide. Penta-treated 2-inch by 6-inch pine boards run parallel to crate on both sides (Figure 5).

Assignment of floor section to location was at random. Each stall area had separate nipple waterers for the sow and the litter.

Fifteen sows are farrowed every eight weeks in an "all-in all-out" management program. After the sows and pigs are removed from the unit, it is cleaned using water at 500- to 600-PSI pressure, then fumigated with formaldehyde gas. Sows are brought to the building on day 109 of gestation and randomly assigned to a stall. Room temperature is a minimum of 70° F, maintained by a thermostatically controlled gas-fired space heater. A 250-watt lamp (one per stall) is suspended 18 inches above the piglet sleeping area. Within 24 hours of birth piglets are needle-teeth clipped, ear notched, tail docked, males castrated, and given an iron injection in the neck muscle. Pigs are weaned at 28 days of age.

Observations for evidence of skin abrasions and other possible injuries were made on days 1, 2, 3, 7 and 14 post-partum. Occurrence and severity of scours were also noted.

RESULTS TO DATE

Piglet performance to 28 days of age is summarized in table 1. Average number of pigs weaned per litter for the 81 litters was 7.7, a survival rate of 87.4%, with average 28-day weight of 6.3 kg. There were no statistically significant differences in performance among the floor groups. Table 2 summarizes the occurrence and severity of knee abrasions. Observations of dewclaw and toe injuries were infrequent and mild, both on the sows and the piglets. Abrasions on piglets frequently occurred during the first competitive nursing. In most cases the abrasion had become covered with a protective crust (or callous formation) by day 3, and definitely by day 7. Lowest value for percent of piglets observed that showed crust formation was for those on the plastic-covered expanded metal, the highest on plastic-covered expanded metal and wood combination. Overall, the higher values were for those floors partly of wood. Evidence of bleeding from abrasions was very limited and occurred mostly on the concrete floor. Average scores for all observed abrasions did not differ significantly among floors. Percent of the piglets in each group showing any form of abrasion or lesion was significantly ($P<.05$) lower with plastic-coated floor than in the other floor groups.

Although neither piglet teat nor vulva necrosis was noted, Penny et al. (1978) reported that they were frequently observed in their units, and Baardson et al. (1980) reported that the incidence of teat and knee necrosis was significantly greater for piglets on concrete slotted floor than on plastic-coated expanded metal floor.

Evidence of scours has been of no consequence to date. Pen cleanliness rating has been highest for the expanded metal-wood floor (Figure 2). Wet areas of the floor have been most frequent on the concrete (Figure 3), second most frequent on the steel-slat-wood floor (Figure 5). This can be minimized on the concrete section by either enlarging the front slotted area or by relocation of the nipple waterers. On the steel slats, sow urine "splattering" and retention of moisture on the wood can cause an appreciable area of wet surface. On the plastic-coated flooring (Figure 1) sow feces tend to dry and plug the openings. This has also been evidenced in another plastic-coated flooring material recently installed in a separate farrowing unit (Figure 6). This flooring appears to minimize abrasion and dewclaw injury to nursing piglets.

SUMMARY

Five different farrowing stall flooring types have been evaluated over a two-year period involving six farrowing groups of 15 sows each. Considering performance, percent of pigs born live that are weaned, number per litter at weaning, and pig weight at weaning have not differed significantly among floor treatments. However, percent weaned and numbers of pigs weaned were highest with the plastic-coated floor and the combination expanded metal-wood floor.

Abrasions and other injuries noted appeared to be of relative insignificance since there were no evidences of systemic infection that could result from bacterial invasion of broken skin areas. Also, individual pig performance did not appear to reflect observed abrasions.

Evidence of bleeding as a result of knee skin abrasions was minimal. It occurred in .5% of the piglets on expanded metal-wood floor, 1.6% of the pigs on concrete and none in the other treatment groups.

Average scores for all observed abrasions did not differ significantly among floor treatments, but percent of the piglets in each group showing any form of abrasion or lesion was significantly ($P<.05$) lower with plastic-coated floor than in the other floor groups.

Table 1. Summary of effects of farrowing crate floors on performance of piglets to 28 days of age

Floor[a]	Number of litters[b]	Average at birth: Number Total	Number Live	Weight, kg Litter	Weight, kg Pig	Average at weaning: % Weaned[c]	Number/ litter	Weight, kg Litter	Weight, kg Pig
Plastic-coated	17	9.9	8.9	13.8	1.56	95.5	8.5	55.0	6.4
Expanded metal and wood	14	10.0	9.3	12.4	1.33	90.0	8.4	53.9	6.4
Concrete	17	9.6	8.3	11.9	1.43	85.5	7.1	45.0	6.4
Plastic-coated and wood	17	10.4	8.8	13.1	1.50	85.0	7.5	43.3	5.8
Metal slats and wood	16	9.9	8.8	12.5	1.42	81.0	7.1	46.9	6.6
Average	16	9.9	8.8	12.7	1.45	87.4	7.7	48.9	6.3

[a] See figures 1 through 5.
[b] Six farrowing groups.
[c] Percent of pigs born live that were weaned.

Table 2. Summary of observations of knee conditions of nursing piglets on different farrowing crate floors

Flooring[a]	Day post-farrow 1	2	3	7	14	Avg.
Avg. knee scores[b]						
Hair rubbed off, %[c]						
P.C.	0	17.7	15.4	7.7	0	8.2
Exp. m & w	4.4	4.4	4.9	20.4	9.1	8.6
Concrete	9.7	2.1	7.9	5.5	5.5	6.1
P.C. & wood	12.7	12.7	11.5	6.0	6.0	9.8
Metal & wood	3.4	16.7	4.8	10.0	7.1	8.4
Avg.	6.0	10.7	8.9	9.9	5.5	
Crust formed over abraised area, %[c,e]						
P.C.	0	0	12.8	30.8	12.8	11.3[1]
Exp. m & w	8.9	20.0	15.9	20.4	6.8	14.4[1,2]
Concrete	2.4	5.3	23.7	27.8	5.5	12.9[1,2]
P.C. & wood	16.4	7.3	30.8	23.8	16.0	18.9[2]
Metal & wood	4.8	4.8	28.6	26.2	11.9	15.3[1,2]
Avg.	6.5	3.9	22.4	25.8	10.6	

(continued)

Skin broken, some evidence of bleeding, %[c]						
P.C.	0	0	0	0	0	0
Exp. m & w	0	0	0	2.3	0	.5
Concrete	0	2.6	2.6	2.8	0	1.6
P.C. & wood	0	0	0	0	0	0
Metal & wood	0	0	0	0	0	0
Avg.	0	.5	.5	1.0	0	
Average score for all observations[d]						
P.C.	0	1.11	1.94	2.18	2.50	1.54
Exp. m & w	2.25	1.84	2.05	2.17	1.68	2.00
Concrete	1.40	2.20	2.30	2.40	1.80	2.02
P.C. & wood	2.10	2.10	2.20	1.90	1.70	2.00
Metal & wood	2.00	1.80	2.40	1.80	1.75	1.95
Avg.	1.55	1.81	2.18	2.09	1.88	
Average percent of pigs showing lesions, %[e]						
P.C.	0	20	43	52	25	28[1]
Exp. m & w	17	42	45	52	50	41[2,3]
Concrete	12	29	57	69	55	44[2,3]
P.C. & wood	30	38	59	68	74	54[3]
Metal & wood	11	42	59	78	57	49[2,3]
Avg.	14	34	53	64	52	

[a] P.C. = plastic-coated expanded metal. Exp. m & w = expanded metal and wood.
[b] Observations of each piglet were made on days 1, 2, 3, 7 and 14 post-farrow. Subjective scores were as follows: 0 = no evidence of skin abrasion; 1 = evidence of hair rubbed off; 2 = area on knee showed abrasive effects of floor, reddish in color; 3 = crust (scab) formed over abraised area; 4 = thickened, callous-like formation over abraded area; and 5 = skin broken, some evidence of bleeding.
[c] Percent of pigs observed showing condition.
[d] Average numerical score for all observations made on each floor type.
[e] Averages with different superscripts differ significantly (P<.05).

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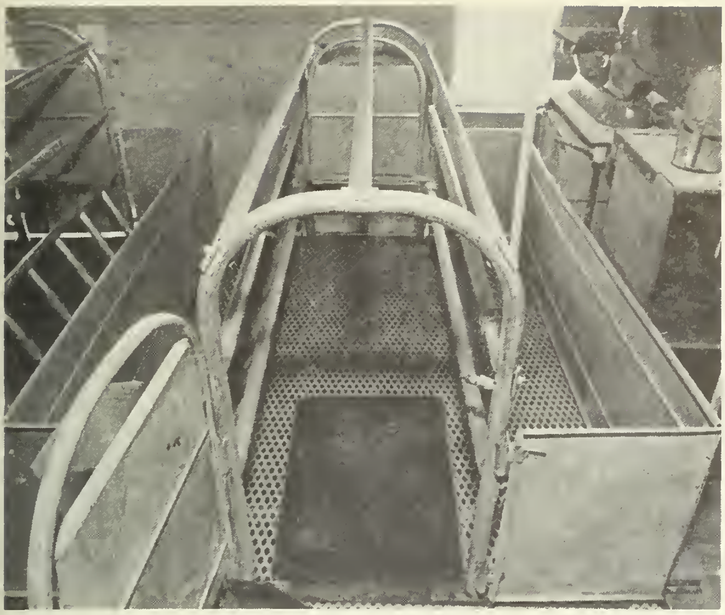

Figure 1. Plastic covered expanded metal (TENDERFOOT) for the 5 feet by 7 feet stall area. The solid metal plate in the front portion is to protect the floor covering from chewing or tearing by the sow.

Figure 2. Combination of wood and expanded metal (No. 9-11 gauge, 3/4 inch flattened) across the front 10 inches and the rear 24 inches of stall floor. Diamond-shaped opening in expanded metal across the rear of the crate lies parallel to the length of the stalls.

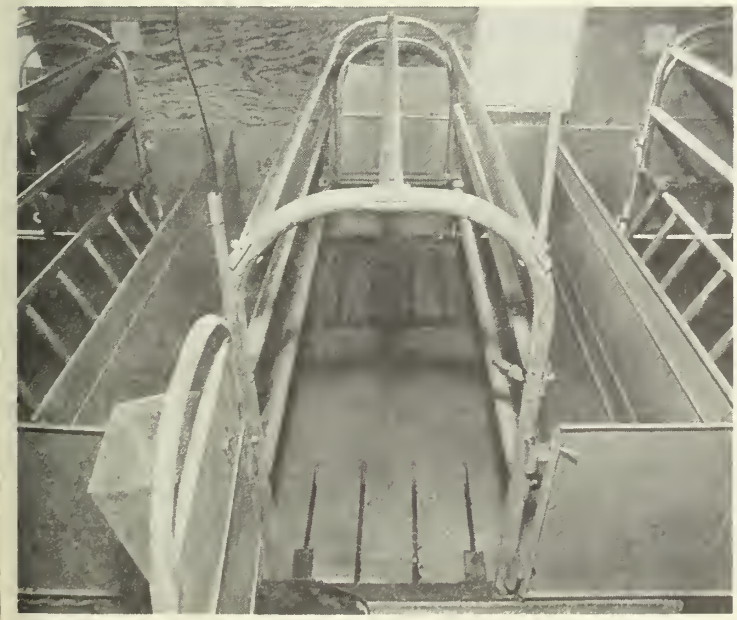

Figure 3. Precast concrete section 5 feet by 7 feet. Rear portion has 1-inch slots 30 inches long spaced at 5 inches. The 1-inch slots are filled with iron bars during and for 24 hours after farrowing. The 1/2-inch slots in front are about 18 inches long.

Figure 4. Combination of plastic-covered metal (TENDERFOOT) and wood. Front and rear portions are 24-inch sections of TENDERFOOT, with penta-treated 2-inch by 6-inch pine boards between.

Figure 5. Combination of steel slats and wood. The slats are 1 inch wide spaced at 1/2 inch, the section being 24 inches wide. Penta-treated 2-inch by 6-inch boards run parallel on each side of the slat section.

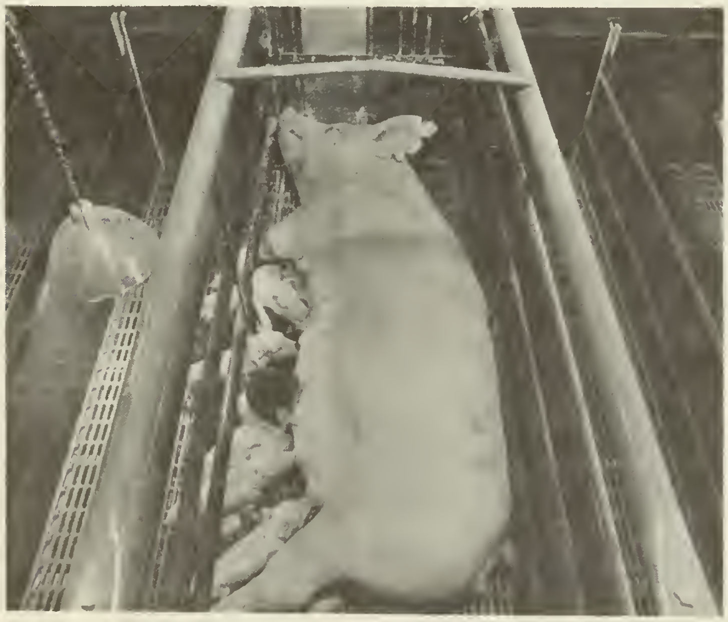

Figure 6. Farrowing crate floor of "welded wire" flooring with plastic cushion cover. Openings are 3/8 by 2 inches.

December, 1981 1981-13

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Tumbling of Bacon

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In recent years, extensive research and increasing acceptance of meat tumbling has occurred in the United States. Tumbling improves pickle incorporation and uniformity of dispersion, cure color development, release of salt soluble proteins which enhance meat binding, external appearance, sliceability, taste and yields in boneless hams. The adaptation of tumbling and its associated advantages to other cured meat products is inevitable. Experiments in our laboratory have shown that when pork bellies are tumbled with a curing pickle, there is rapid absorption of pickle into the bellies. Moreover, the tumbling enhances the ability of the bellies to hold the pickle after tumbling. Therefore, an experiment was designed to determine the influence of tumbling on pickle incorporation, yield, and quality of bacon.

The influence of tumbling on pickle incorporation, yield and quality of bacon was evaluated. Pork bellies (300) were assigned to five processing treatment groups: multineedle injection, multineedle injection then vacuum tumble, vacuum tumble plus free pickle, vacuum tumble (with injection needles exposed) plus free pickle, and vacuum tumble while pickle injecting. Although treatment differences existed for pickle incorporation and yield, no treatment was consistently superior for pickle incorporation, yield and quality. Nitrosopyrrolidine levels in samples from all treatments were acceptable according to USDA standards. A positive correlation existed between carcass backfat thickness and pickle incorporation in bellies multineedle injected, but negatively correlated when tumbled. Carcass backfat thickness and hot carcass weight were positively correlated to final bacon yield regardless of treatment.

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December, 1981 1981-14
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Value of Wheat Middlings in Swine Diets[1,2]

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Wheat middlings (WM) are a by-product of the wheat milling industry, consisting mostly of fine particles of bran and germ. Wheat middlings are classified as having at least 15.5% crude protein (CP), 88% dry matter (DM), and not more than 7.5% crude fiber (Hubbell, 1981).

Previous experiments have shown WM to be adequate as a feedstuff for finishing swine, although performance may not be equivalent to that obtained with a corn-soy diet (Conrad et al., 1967; Collings, 1977; Erickson, 1977; Pals and Ewan, 1978). When fed diets containing WM, pigs tend to consume more feed, possibly due to the high fiber content (i.e., lower metabolizable energy level). This increase in feed consumption has been explained on the basis that the pig eats to meet its energy requirements to the extent that its stomach capacity is not limiting (Conrad et al., 1967).

The WM used in these trials were all from the same shipment and were obtained from Seimer Milling Co., Teutopolis, Illinois. Laboratory analysis determined that the wheat middlings contained 15.76% CP, .55% lysine, and 3.98 kcal/g gross energy at 86.90% DM.

Initially, a metabolism trial was conducted to determine the metabolizable energy (ME) content of the WM. This measured ME value was then used in the formulation of diets for the feeding trials. Starter and finisher pigs were used in the metabolism trial in order to obtain ME values for two classes of swine.

The determined ME values for the diets and the calculated ME values for WM fed to starter and finisher pigs are shown in table 1. The basal diet had an ME value of 3.46 kcal/g for starter pigs and 3.38 kcal/g for finisher pigs. These values were higher ($P<.05$) than those for the diets containing 20% or 40% WM (3.35 kcal/g and 3.21 kcal/g for starter pigs, and 3.20 and 3.09 kcal/g for finisher pigs, respectively). The values shown in parentheses in the table are ME values adjusted for nitrogen retention. The adjustment factor of 6.77 kcal/g of urinary nitrogen suggested by Diggs et al. (1965) was used. As the level of WM increased in the diet, ME and adjusted ME values decreased linearly ($P<.001$) for both starter pigs and finisher pigs.

[1] Research funded in part by a grant from Farmland Industries, Inc., Kansas City, Missouri.
[2] Thanks are due to Scott Williamson, Ron Brewer, and Steve Heffernan for their assistance.

V. L. O'Hearn, R. P. Chapple and J. A. Cuaron are Ph.D. students at the University of Illinois. R. A. Easter is Associate Professor of Swine Nutrition.

The ME values obtained for the wheat middlings (2.89 kcal/g, 2.84 adjusted for starter pigs and 2.57 kcal/g, 2.44 adjusted for finisher pigs) are slightly lower than the 2.94 kcal/g reported by NRC (1979) for swine. The difference in the ME values between the two categories of pigs suggests that the starter pig may be better able to utilize WM in the diet.

Table 1. Summary of measured metabolizable energy values for the diets and calculated values for wheat middlings[a]

	Metabolizable energy, kcal/g							
	Diet						Calculated ME	
	Basal[b]		20% WM		40% WM		WM	
Starter pigs	3.46	(3.44)	3.35	(3.33)	3.21	(3.18)	2.89	(2.84)
Finisher pigs	3.38	(3.32)	3.20	(3.12)	3.09	(3.01)	2.57	(2.44)

[a] Average initial weight of starter pigs was 9.45 kg and average initial weight of finisher pigs was 57.73 kg.

[b] Basal diet was an 18% diet containing SBM and cornstarch; WM were added to the diet at the expense of cornstarch.

There was a linear decrease in ME as the level of WM increased in diet of both starter pigs ($P<.0001$) and finisher pigs ($P<.05$). This is in agreement with Bowland et al. (1970) and Just et al. (1976) who found that ME values decreased with increasing levels of crude fiber. The average calculated ME value for starter pigs was 2.89 kcal/g and this value was used in the formulation of the diets used in the subsequent feeding trials.

Feeding Trial 1

The objective of the first feeding trial was to determine if energy is the limiting factor in the use of wheat middlings in swine diets. Eighty crossbred barrows and gilts averaging 7.74 kg initially were randomly assigned to treatments (table 2) from outcome groups formed on the basis of weight, sex, and ancestry. Diets are shown in table 3. There were four treatments with four replicate pens of five pigs per pen. Diet 4 was formulated to contain the same ME level as the basal diet.

Table 2. Treatments, Trial 1

1)	Basal
2)	As 1 + 6.64% tallow
3)	As 1 + 30% WM
4)	As 3 + 6.64% tallow

This trial was conducted over a four-week period. Initial and final weights were obtained and feed consumption recorded. Data were subjected to the appropriate analysis of variance (Steele and Torrie, 1960).

Table 3. Composition of diets, Trial 1[a]

	Diets			
Ingredient	Basal	Basal + tallow	Wheat middlings	Wheat middlings + tallow
Corn	72.87	64.81	48.20	40.14
Soybean meal (48%)	23.61	25.07	18.23	19.69
Wheat middlings	--	--	30.00	30.00
Tallow	--	6.64	--	6.64
Dicalcium phosphate	1.50	1.50	1.50	1.50
Limestone	1.00	1.00	1.00	1.00
Illini vitamin mix[b]	.20	.20	.20	.20
Trace mineral salt[c]	.35	.35	.35	.35
ASP-250	.25	.25	.25	.25
L-lysine·HCl	.22	.22	.27	.27
	100.00	100.00	100.00	100.00

[a]Wheat middlings were substituted for corn and soybean meal. Diets were formulated to a constant level of crude protein.

[b]Contributed the following per kilogram: vitamin A, 3,300 IU; vitamin D_2, 330 IU; α-tocopheryl acetate, 22 IU; riboflavin, 1.1 mg; calcium pantothenate, 6.57 mg; choline chloride, 165.0 mg; vitamin B_{12}, 17.6 micrograms.

[c]Easter and Baker, 1977.

Performance data obtained are shown in table 4. In this trial there was no difference in pig performance due to the addition of 30% WM with or without added tallow.

Because of the lower ME value of WM as compared to corn (2.89 kcal/g and 3.33 kcal/g, respectively), pigs fed diets containing WM should consume more feed as shown by Conrad et al. (1967). The addition of wheat middlings did not significantly affect intake; however, there was a substantial numerical increase in daily feed consumption that was reversed by the addition of energy in the form of tallow (diet 4).

Table 4. Performance of crossbred starter pigs fed diets containing 30% wheat middlings with or without added tallow

Diet	ADG, kg[a]	ADF, kg	G/F
1) Basal	.48	.84	.57
2) As 1 + tallow	.49	.83	.59
3) As 1 + 30% wheat mids[c]	.51	.95	.54
4) As 3 + tallow	.46	.87	.53
Pooled Std. Error	.020	.042	.031

[a]Average initial weight, 7.74 kg.

The fact that there was no significant effect on pig performance due to the addition of wheat middlings suggested that greater levels of middlings should be used. Therefore, the subsequent trial was designed to determine the level of WM at which pig performance would be depressed.

Feeding Trial 2

One hundred twenty crossbred barrows and gilts with an average initial weight of 8.59 kg were assigned to treatments on the basis of weight, sex, and ancestry. Treatments are shown in table 5 and diets in table 6. There were four treatments with five replicate pens of six pigs per pen.

Table 5. Treatments, Trial 2

1) Basal
2) As 1 + 28.33% WM
3) As 1 + 56.66% WM
4) As 1 + 85.00 WM

This feeding trial was conducted for five weeks. Initial and final weights were measured and feed consumption recorded. Data were subjected to analysis of variance (Steele and Torrie, 1960).

Table 6. Composition of diets, Trial 2[a]

	Diets			
Ingredients	Basal	28.33% Wheat mids	56.66% Wheat mids	85.00% Wheat mids
Corn	73.54	50.27	26.90	3.63
Soybean meal (48%)	23.57	18.51	13.46	8.48
Wheat middlings	--	28.33	56.66	85.00
Def. rock phosphate	1.46	1.46	1.46	1.46
Limestone	.73	.73	.73	.73
Trace mineral salt[b]	.35	.35	.35	.35
Illini Vitamin Mix[b]	.10	.10	.10	.10
CSP·250	.25	.25	.25	.25
	100.00	100.00	100.00	100.00

[a]Wheat middlings were substituted for corn and soybean meal.
[b]See table 3.

Performance data obtained are shown in table 7. As the level of WM in the diet increased, both ADG and G/F of the pigs decreased ($P<.001$). Pigs fed the highest level of WM (85.00%) exhibited a decrease in feed intake ($P<.05$). This effect was unexpected; therefore, Trial 3 was designed to determine if either bulk or protein quality is a limiting factor in feed intake and pig growth.

Table 7. Performance of crossbred starter pigs fed graded levels of wheat middlings

Diet	ADG, kg[a]	ADF, kg	G/F
1) Basal	.46	.93	.50
2) As 1 + 28.33% wheat middlings	.41	.88	.46
3) As 1 + 56.66% wheat middlings	.37	.88	.42
4) As 1 + 85.00% wheat middlings	.28	.72	.39
Pooled Std. Error	.001	.026	.009

[a]Average initial weight, 8.59 kg.

Feeding Trial 3

In this trial pelleting was employed as a means of increasing the density of the WM diets and lysine was added to correct the calculated deficiency due to WM. Ninety crossbred barrows and gilts were assigned to treatments (table 10) on the basis of weight, sex, and ancestry. There were six treatments with three replicate pens of five pigs per pen. Diets are shown in table 9. The trial duration was three weeks. Initial and final weights were obtained and feed consumption recorded. Data were subjected to analysis of variance (Steele and Torrie, 1960).

Table 8. Treatments, Trial 3

1) Basal
2) As 1 + 85.00% WM
3) As 2 + L-lysine·HCl
4) As 1 pelleted
5) As 2 pelleted
6) As 3 pelleted

Table 9. Composition of diets, Trial 3

Ingredients	Basal	85% wheat middlings	85% wheat middlings + lysine
Corn	73.54	3.63	3.37
Soybean meal (48%)	23.57	8.48	8.48
Wheat middlings[a]	--	85.00	85.00
Def. rock phosphate	1.46	1.46	1.46
Limestone	.73	.73	.73
Trace mineral salt[b]	.35	.35	.35
Illini Vitamin Mix[b]	.10	.10	.10
CSP·250	.25	.25	.25
L-lysine·HCl	--	--	.26
	100.00	100.00	100.00

Table 9. (Continued)

Ingredient	Basal	85% wheat middlings	85% wheat middlings + lysine
Laboratory analysis			
Meal			
CP, %	17.73	16.90	17.40
Lysine, %	.75	.55	.78
Pelleted			
CP, %	17.92	17.49	17.93
Lysine, %	.76	.58	.72

[a]Wheat middlings were substituted for corn and soybean meal.
[b]See table 3.

Results, Trial 3

Pig performance is shown in table 10. The trial was terminated at the end of three weeks. The addition of lysine to the WM diet improved performance of pigs over that observed with pigs fed the WM diet without added lysine, but did not improve performance ($P<.001$) to the level observed when pigs were fed the basal diet.

Pelleting of the diets had no effect on performance of pigs fed the basal diet, but appeared to improve performance of pigs fed the WM diets with or without added lysine.

The results of this trial suggest that protein quality and energy may be limiting factors in the use of WM in swine diets. The addition of lysine to the 85% WM diet improved pig performance, and pelleting of the diets appeared to increase intake, although not significantly ($P<.06$).

Table 10. Performance of pigs fed 85.00% WM with or without added lysine[a]

Diet	ADG, kg	ADF, kg	G/F
1) Basel	.52	.99	.53
2) As 1 + 85.00% WM	.29	.76	.38
3) As 2 + L-lysine·HCl	.38	.84	.45
4) As 1 pelleted	.52	.98	.53
5) As 2 pelleted	.33	.85	.39
6) As 3 pelleted	.43	.91	.47
Pooled Std. Error	.028	.031	.015

[a]Average initial weight was 9.60 kg.

Summary

A metabolism was conducted to determine the ME value of WM when fed to swine. Two categories of pigs were used in the study to determine the effect of age on ME values. An ME value for WM of 2.89 kcal/g (2.84 adjusted) was determined for starter pigs and 2.57 kcal/g (2.44 adjusted) was determined for finisher pigs. These values indicate that there may be an age effect on ME values of WM, and that in this study starter pigs were better able to utilize WM in the diet.

Three feeding trials were conducted to determine the feeding value of WM and determine limiting factors. In the first trial, tallow was added to a diet containing 30% WM to determine if energy was the limiting factor. There were no differences in pig performance, indicating that the addition of WM to the diet at 30% had no effect.

The second trial was to determine the level at which WM would depress overall performance. At 85% WM average daily gain, average daily feed, and the gain-to-feed ration were all depressed. This level of WM (85%) was then used in the third feeding trial.

In trial three, lysine was added to the WM diet and diets were fed in meal or pelleted forms to determine if protein quality or bulk of the diets were limiting factors. The addition of lysine to the WM diet improved performance of the pigs over those on the WM diet without added lysine, although performance did not equal that of pigs fed the basal diet. Pelleting of the diets appeared to increase intake, although the effect was not significant.

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December, 1981 1981-15

University of Illinois at Urbana-Champaign

College of Agriculture
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Genetic Engineering in Swine Improvement: What Are the Prospects?

BEN A. RASMUSEN

Recent advances in techniques of genetic engineering are making it possible to transfer genes from rabbits to mice, and even from people to bacteria. What are the prospects for use of these techniques in swine improvement?

In order to use genes in genetic engineering, we need to identify them. In humans, thousands of different genes are known, and it has been suggested that some time in the foreseeable future we will be able to characterize the entire genetic material (DNA sequence) for all of the genes in an infant and predict his adult appearance and behavior from his genetic makeup. In mice, the same techniques now available to transfer genes from one mouse to another might conceivably be used to transfer genes in pigs in order to produce pork more efficiently.

However, genetic research with swine is far behind that with man and mouse. Only a few genes have been identified in pigs, and we know little about the genetic material in swine. We have identified more genes in swine for blood groups (red blood cell antigens) than for anything else. One of the blood group genes (referred to as H) identifies a genetic locus which is closely linked to several genes for other traits. This group of linked genes includes, in addition to the gene for H red blood cell antigens, genes for two red blood cell enzymes, PHI (phosphohexose isomerase) and 6-PGD (6-phosphogluconate dehydrogenase), as well as genes for halothane sensitivity (an indicator of susceptibility to the porcine stress syndrome, PSS) and expression of A and O blood groups.

Among these linked genes, the gene for PSS has the most easily identifiable effects on pork production. It causes death losses, and the PSE (pale, soft exudative) pork often associated with PSS also reduces the efficiency of pork production. There is evidence than at least two of the genes linked to the gene for PSS (the genes for H blood groups and PHI enzymes) also have an effect on pork production.

A research project is underway at Urbana to study the linkage relationships between genes for PSS and other genes, and to study how the genes act, especially in their effects on fertility and productivity. Possible methods to identify carriers of the gene for PSS are being evaluated. More is now known about this group of linked genes than about any other genes in swine. We hope that what we are learning about these genes will provide information that will be useful in pioneering applications of techniques of genetic engineering in swine improvement.

Ben A. Rasmusen is Professor of Animal Genetics with the Department of Animal Science at the University of Illinois at Urbana-Champaign.

December, 1981 1981-16
University of Illinois at Urbana-Champaign
College of Agriculture
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Evaluation of Different Methods of Utilizing High Moisture Corn in Diets for Gravid Swine

S.A. WILLIAMSON, R.P. CHAPPLE, AND R.A. EASTER

INTRODUCTION

The potential for using high moisture grains to substantially reduce the demand for drying fuel on Illinois farms is well recognized. Additionally, earlier grain harvest may be possible at a time when the crop residue, i.e., stalkage, is of greater nutritional value for ruminant feed.

It is well documented that both high-moisture corn and sorghum can be utilized equally as well as the dry (<14% moisture) grain. Most experimental evidence indicates that the high-moisture grain should be mixed with supplementary ingredients (e.g., protein, vitamins and minerals) and offered to the pig as a complete feed. When allowed to consume high-moisture grain and supplement as separate feeds the pig tends to over-eat one or the other, thus failing to "balance" its diet. This results in reduced rate of gain and feed efficiency.

Very little research has been conducted to determine the value of high-moisture corn for gestating swine. This experiment was designed to compare dry and high-moisture corn diets using two high-moisture corn-feeding methods.

MATERIALS AND METHODS

The dietary treatments in this experiment were:

1. A 12% crude protein, corn-soybean meal diet fed at the rate of 1.9 kg of diet/female/day.

2. A high-moisture corn-soybean meal diet formulated to contain the same amount of crude protein, on a dry matter basis, as the 12% diet used in treatment 1. The quantity of this diet fed to each animal each day was adjusted to provide the same daily dry matter intake as provided by treatment 1.

3. A free-choice access to high-moisture corn and a protein supplement.

A 35% crude protein supplement was formulated for use in preparation of the diets for treatments 1 and 2, and as the high-moisture corn supplement for use in treatment 3. The percentage composition of the supplement is shown in table 1. In the case of treatment 1, this supplement was blended with dry corn in the proportion of 88.5% corn, 11.5% supplement to form a 12% crude protein gestation

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diet. The diet used for treatment 2 was prepared by mixing high moisture corn and supplement in a ratio that would give identical composition, on a dry matter basis, to the treatment 1 diet.

Table 1. Composition of complete protein supplement[a]

Ingredient	%
Soybean meal, 48.5% CP	72.07
Defluorinated rock phosphate	18.30
Ground limestone	5.48
Trace mineral salt	3.20
Illini vitamin mix	.95
	100.00

[a]Expressed on an "As Fed" basis.

Individual females in three farrowing groups (group 1 consisted of first-litter gilts; groups 2 and 3 included both gilts and sows) were mated to a Chester White boar on the first day of estrus and to a second Chester White boar on the second day of estrus. From breeding until an average day-30 of gestation the gilts/sows were penned individually in gestation stalls and fed 1.9 kg of the treatment 1 diet per day. When a group averaged 30 days postbreeding each pig was checked for pregnancy using an ultrasonic device; pregnant females were then allotted at random to the three treatments from outcome groups formed on the basis of parity and weight.

During the experimental feeding period, the animals were housed in a gestation building equipped with mechanical ventilation. Within the building gilts or sows were housed in pen-groups of no more than ten animals. All females within a pen were assigned to the same treatment. In the case of treatments 1 and 2 the pens were equipped with individual feeding stalls. Gilts or sows assigned to treatment 3 were placed in pens containing two self-feeders: one for high-moisture corn and one for the complete protein supplement. The high moisture corn diet used in treatment 2 was prepared fresh every third day in order to minimize spoilage. At the same time, fresh, high-moisture corn was added to the feeders used for treatment 3.

Each female was weighed, when assigned to experimental treatment and again on day-109 of gestation. Gilts and sows were moved to the farrowing unit on the 109th day of pregnancy. From then until litters were weaned at 28 days of age a 16% crude protein lactation diet was fed. Until farrowing, each female received 1.9 kg of diet per day; feed was provided *ad libitum* from farrowing until weaning. The sow and piglets were weighed within 12 hours of farrowing and again at weaning. Litter data (e.g., number of pigs born, number born alive) were recorded for each litter. Within 24 hours of birth, needle teeth were clipped, the tails were docked, excess umbilicus was trimmed, and 100 mg of iron dextran was administrated to each piglet by intramuscular injection. Each sow was allowed to nurse her natural litter (i.e., there was no inter-litter transfers). An 18% crude protein corn-soybean meal creep diet was made available to the piglets beginning at 14 days of age.

Date were analyzed statistically using the Statistical Analysis System[1] computing package.

Table 2. Feed consumption, weight gain and reproductive performance of gilts and sows fed gestation diets containing air-dry or high-moisture corn[a]

Criteria	Treatment 1 12% crude protein air-dry corn diet	Treatment 2 As treatment 1 using high -moisture corn	Treatment 3 Free-choice high-moisture corn and protein supplement
No. of observations			
Gilts	15	31	28
Sows	16	18	20
Gestation feed intake, kg/day (as-fed basis)	1.9^c	2.3^d	4.2^e
Lactation feed intake, kg/28 days	111.6^c	118.5^c	95.0^d
Gestation weight gain, kg[b]			
Gilts	30.03^c	35.5^c	44.64^d
Sows	30.78^c	33.92^c	71.90^d
Average	30.42^c	34.66^c	56.00^d
Lactation weight loss, kg	-11.1^c	-8.5^c	-18.9^d
Total pigs born/litter	11.0	10.6	10.2
Pigs born alive/litter	10.0	9.7	9.2
Pigs weaned/litter	8.2	8.0	7.5
Mortality of pigs born alive, %	17.0	16.3	16.7
Live pigs avg.			
Litter birth wt., kg	14.43	14.10	13.94
Individual pig wt., kg	1.48	1.47	1.54
Avg. 28-day wt. of litters, kg	51.15	50.62	48.77
Pigs, kg	6.24	6.33	6.50

[a]Values have been adjusted by covariance analysis to remove effects of parity (gilt vs. sow) and farrowing group.

[b]Gestation weight gain was calculated by subtracting weight at day-30 from the weight at day-109 of gestation.

[c,d,e]Values within a row with different superscripts are different ($P < .05$).

RESULTS AND DISCUSSION

Of the 128 sows completing the experiment there were 31, 49 and 48 assigned to treatments 1, 2 and 3, respectively. There was no indication that treatment

[1]Statistical Analysis System. 1979. SAS User's Guide (1979 Edition). The SAS Institute, Cary, North Carolina 27511.

affected structural soundness during pregnancy, farrowing difficulty or the incidence of diarrhea in suckling piglets.

The feed consumption data (table 2) show that feed intake was increased ($P<.05$) when the gilts/sows were given an opportunity to eat free-choice.

There was no difference ($P>.10$) in gestation weight gain between treatments 1 and 2; gain for those animals receiving treatment 3 was considerably greater ($P<.05$) than for those receiving treatments 1 or 2. This was not unexpected in view of the increase in feed intake by gilts and sows assigned to treatment 3. The interaction of parity and feed intake was tested and found significant ($P<.05$). This is apparent from the data which indicates that second-litter sows assigned to treatment 3 gained an average of 27.26 kg more in body weight than did first-litter gilts receiving the same treatment. The loss in maternal body weight during lactation followed the pattern of gestation weight gain. The animals gaining the most weight during gestation (treatment 3) lost more weight ($P<.05$) than those assigned to treatments 1 or 2.

None of the reproductive criteria measured were significantly affected by treatment. However, those gilts and sows assigned to treatment 3 tended to farrow smaller litters of pigs that were slightly heavier at birth and weaning. This tendency is consistent with the reports by Baker *et al.* (1969) and Frobish *et al.* (1973) that excessive energy intake during gestation increases fetal wastage but results in increased size of surviving pigs.

These data support the use of high-moisture corn diets for the gestating gilts or sows when economic and management considerations favor its use. It is apparent that the best performance is realized when the high-moisture corn is fed in a complete, mixed diet and in a quantity that will provide the recommended levels of daily dry matter intake. As with air-dry corn diets, both gilts and sows will overconsume high-moisture feeds if given the opportunity

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DECEMBER, 1982

SWINE RESEARCH REPORTS

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Contents

1982-1 Effective Use of High-Oil Corn in Diets for Growing-Finishing Swine
K.L. Adams, C.C. Lin, and A.H. Jensen

1982-2 Sunflower Seeds in Diets for Young Pigs
K.L. Adams, C.C. Lin, and A.H. Jensen

1982-3 Why Don't All Pregnant Gilts Go to Term?
Philip Dziuk

1982-4 Inducing Farrowing by Using Prostaglandin
P.A. Eichen, B. Brohammer, L.H. Thompson, and A.H. Jensen

1982-5 Effect of Dietary Level of Alfalfa Hay and of Lasalocid on Performance of Growing-Finishing Swine
D.P. Holzgraefe, J.D. Tracy, and A.H. Jensen

1982-6 Gestation Environment Alternatives
J.M. McFarlane, S.E. Curtis, G.L. Morris, and P.J. Dziuk

1982-7 Studies of Carbon Monoxide Toxicosis in Swine
G.L. Morris, S.E. Curtis, and J. Simon

1982-8 Effect of Copper Sulfate as a Growth Promoter
V.L. O'Hearn and R.A. Easter

1982-9 Improvement of Storage Life and Palatability of Pork Patties
S.T. Plese, P.J. Bechtel, and J.R. Romans

1982-10 Slaughter Factors that Affect Pork Quality
E.L. Voogd and T.R. Carr

1982-11 Effects of Attending Farrowing
H.L. Winship, S.E. Curtis, G.L. Morris, and H.W. Norton

1982-12 Lysine Supplementation of Sorghum-Sesame Seed Meal Lactation Diets and Productive Response of Gilts and Sows
J.A. Cuaron, R.P. Chapple, and R.A. Easter

Urbana, Illinois December, 1982

Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. WILLIAM R. OSCHWALD, Director, Cooperative Extension Service, University of Illinois at Urbana-Champaign. The Illinois Cooperative Extension Service provides equal opportunities in programs and employment.

USING THE METRIC SYSTEM

Most scientific publications require that units of measurements be reported in the metric system (kilograms, centimeters, etc.). The following conversion factors may be beneficial in helping to understand units of measurements that a reader may encounter in this report.

1 ounce = 28.50 grams	1 gram = 0.03527 ounce
1 pound = 453.6 grams	1 kilogram = 35.274 ounces
1 pound = 0.4536 kilogram	1 kilogram = 2.205 pounds
1 inch = 2.54 centimeters	1 metric ton (1000 kilograms) = 2205 pounds
1 foot = 30.48 centimeters	1 centimeter = 0.394 inch
1 yard = 0.9144 meter	1 meter = 39.37 inches
1 mile = 1.609 kilometers	1 kilometer = 0.6214 mile
1 square inch = 6.452 square centimeters	1 square centimeter = 0.155 square inch
1 acre = 0.4047 hectare	1 hectare = 2.471 acres
1 cubic inch = 16.387 cubic centimeters	1 cubic centimeter = 0.061 cubic inch
1 cubic yard = 0.7646 cubic meter	1 cubic meter = 35.315 cubic feet
1 fluid ounce = 29.573 milliliters	1 cubic meter = 1.308 cubic yards
1 liquid pint = 0.4732 liter	1 milliliter = 0.0338 fluid ounces
1 liquid quart = 0.9463 liter	1 liter = 33.81 fluid ounces
1 gallon = 3.7853 liters	1 liter = 2.1134 pints
	1 liter = 1.057 quarts
	1 kiloliter = 264.18 gallons

December, 1982 1982-1
University of Illinois at Urbana-Champaign
College of Agriculture Agricultural Experiment Station
Cooperative Extension Service Department of Animal Science

Effective Use of High-Oil Corn in Diets for Growing-Finishing Swine

K.L. ADAMS, C.C. LIN, AND A.H. JENSEN

The results of early tests to evaluate high-oil corn (7.5% oil) in diets for swine were reported in the 1981 Swine Research Reports. The high-oil corn was efficiently utilized by four-week-old pigs. When comparable dietary calorie-lysine ratios were maintained, high-oil corn was equal to regular corn (3.5% oil) plus corn oil (Adams and Jensen, 1981).

Two additional studies were conducted. In Trial I, diets containing high-oil (7.5%) corn were formulated on the basis of either the analyzed crude protein or lysine content of the corn. In Trial II regular corn (3.5% oil) and high-oil (7.5% oil) were compared in diets for growing-finishing pigs.

EXPERIMENTAL PROCEDURES

In Trial I, 108 pigs averaging about 10 kg in weight were used and the trial was for 32 days. In Trial II, 192 pigs averaging about 35 kg were used and fed to market weight. In Trial I the pigs were confined to totally slotted floor pens in an environmentally regulated building. Feed and water were available from a self-feeder and a nipple waterer, respectively, in each pen. Diets were formulated to contain 18, 20 or 22% crude protein, without and with supplemental lysine (table 1). The lysine was added since the high-oil corn assayed 10.8% crude protein and .25% lysine. Thus, the 18% crude protein diet contained only .79% lysine which is inadequate for the four-week-old pig.

In Trial II the pigs were confined to partially slotted floor pens in an environmentally regulated building. Composition of the rations is shown in table 2. Diet 1 was of regular corn-soybean meal and served as control. Diet 2 was high-oil corn-soybean meal isoprotein to Diet 1. Diet 3 was high-oil corn-soybean meal isolysine to Diet 1, while Diets 4 and 5 were calculated to be of about the same calorie:% lysine ratio as Diet 1. Diet 6 was of regular corn-soybean meal isolysine with Diets 4 and 5 and corn oil added to provide a similar calorie:% lysine ratio. Dietary crude protein levels were decreased by two percentage points (.18% lysine) when the pigs averaged about 50 kilograms. Four animals from each dietary treatment were slaughtered at about 100 kg and carcass measurements were made.

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RESULTS

The results of Trial I are shown in table 3. The 18% crude protein diet containing .79% lysine was inadequate for maximum daily gain and feed efficiency. When the lysine level was increased to .95%, gain and feed efficiency were improved. Average gain for the nonsupplemented and lysine-supplemented group did not differ significantly, but average daily feed was decreased and gain/feed increased with lysine supplementation. The most efficient gains were obtained when the lysine level was 1.08% or higher and the calorie:% lysine ratio was 1.7 Mcal:% lysine, or lower.

In Trial II (table 4) dietary treatment significantly affected daily gain and gain/feed values during the first 28 days. Lowest gain and gain/feed were obtained with Diet 2, high-oil corn diet isonitrogenous with Diet I but lower in lysine (.72%). Increasing the lysine level in the high-oil corn diets with either synthetic lysine or soybean meal lysine improved gain and gain/feed values. Gain/feed values were highest when the diets contained .84% lysine (high-oil corn diets 4 and 5 and regular corn plus corn oil diet 6). For the total approximately 105-day feeding period differences in daily gain, daily feed and gain/feed values among dietary treatments were not statistically significant. However, the average daily gain values were highest with Diets 3, 4, 5 (high-oil corn) and 6 (regular corn) and highest gain/feed values were with Diets 4, 5, and 6. When calorie:% lysine ratios were the same the high-oil corn diets (Diets 4 and 5) were as efficiently used as the regular corn plus corn oil diet (Diet 6).

Dietary treatment had no significant effect on carcass, based on measurements of backfat thickness, loin-eye area and length.

SUMMARY

High-oil corn (7.5%) was effectively used in diets for four-week-old pigs when calorie:% lysine ratios were comparable to those in the regular corn (3.5% oil) - soybean meal control diet.

When high-oil corn diets were fed to pigs from 16 to 100 kg in weight rates of gain were equal to or slightly better than those by pigs fed a regular corn-soybean meal diet. Feed efficiency was highest with the high-oil corn diets containing adequate lysine.

Carcass length, carcass backfat thickness and loin-eye areas were similar among treatments.

Table 1. Composition of Diets Used In Trial I

Lysine added, %	-	-	-	.20	.20	.15
High-oil corn[a]	77.30	72.30	67.00	77.10	72.10	66.85
Solvent soybean meal[a]	20.00	25.00	30.30	20.00	25.00	30.30
Defl. rock phos.	1.25	1.25	1.25	1.25	1.25	1.25
Ground limestone	.75	.75	.75	.75	.75	.75
TM salt	.35	.35	.35	.35	.35	.35
Vitamin antibiotic mix	.35	.35	.35	.35	.35	.35
Lysine (98% L-Lysine·HCl)	-	-	-	.20	.20	.15
	100.00	100.00	100.00	100.00	100.00	100.00

Table continued on next page

Table 1 (continued)

Lysine added, %	-	-	-	.20	.20	.15
Calculated:						
Crude protein, %	18.0	20.0	22.0	18.0	20.0	22.0
Lysine, %	.79	0.93	1.08	.95	1.09	1.20
Fat, %	5.90	5.63	5.18	5.90	5.63	5.18
GE, kcal/lb	1840	1859	1841	1840	1859	1811
Kcal/% lysine	2329	1999	1705	1940	1705	1505

[a]Assay values:

	C.P.	Lysine	GE, kcal/lb
High-oil corn	10.8%	.25%	1888
Soybean meal	48.5%	3.0 %	1901

Table 2. Composition of Diets Used in Trial II

Ration Number	1	2	3	4	5	6
Regular corn[a]	77.85	-	-	-	-	72.35
High-oil corn	-	81.60	78.35	78.31	77.35	-
Soybean meal	19.50	15.75	19.00	19.00	20.00	21.00
Dicalcium phosphate	1.25	1.25	1.25	1.25	1.25	1.25
Ground limestone	.75	.75	.75	.75	.75	.75
TM salt (Se)	.35	.35	.35	.35	.35	.35
Illini Vit. Mix	.10	.10	.10	.10	.10	.10
Aurofac-10	.20	.20	.20	.20	.20	.20
Corn oil	-	-	-	-	-	4.00
Lysine-HCl (78% L)	-	-	-	.04	-	-
	100.00	100.00	100.00	100.00	100.00	100.00
Calculated:						
Crude protein, %	16.25	16.22	17.40	17.40	17.76	16.51
Lysine, %	.80	.72	.81	.84	.84	.84
GE, kcal/lb	1743	1842	1843	1842	1842	1837
GE, kcal/% lysine	2182	2558	2275	2193	2193	2187

[a]Assay values:

	Gross Energy	Percent		
	(kcal/lb)	C.P.	Lysine	Fat
Corn	1761	9.1	.23	-
High-oil corn	1888	10.8	.26	-
Soybean meal	1901	47.0	3.20	-
Corn oil	3840	-	-	100

Table 3. Summary of Effects of Dietary Lysine and Crude Protein Levels in High-Oil Corn Diets On Performance of Young Pigs

	No added lysine			Added lysine		
Dietary protein, %	18	20	22	18	20	22
Dietary lysine, %	.79	.93	1.08	.95	1.09	1.20
Mcal:% lysine	2.32	2.00	1.70	1.94	1.70	1.50
Average initial wt., kg[a]	10.9	10.4	11.0	10.8	10.0	9.9
Average daily gain, kg[b]	.55	.62	.61	.59	.59	.60
Average daily feed, kg[c]	1.25	1.31	1.23	1.19	1.14	1.18
Average gain/feed[b,d]	.436	.473	.496	.496	.517	.508

[a]Each value is an average for three pens of six pigs each. Trial was of 32 days duration.

[b]Linear effect (P<.05) of protein (lysine) level in treatments without supplemental lysine.

[c]Lysine-supplemented groups consumed less (P<.05) feed than the nonsupplemented groups.

[d]Lysine-supplemented groups had higher (P<.05) gain/feed values than the nonsupplemented groups.

Table 4. Summary of Results of Trial II

Dietary Corn	Regular	High-oil				Regular
Diet number	1	2	3	4	5	6
Dietary C.P., %[a]	16.2	16.2	17.4	17.4	17.8	16.5
Dietary lysine, %	.80	.72	.81	.84	.84	.84
Added corn oil, %	--	--	--	--	--	4.00
Average initial weight, kg[b]	16.3	16.4	15.9	15.7	15.5	15.3
First 28-days						
Average daily gain, kg[c]	.45[1,2]	.42[1]	.48[1,2]	.56[3]	.50[2,3]	.51[2,3]
Average daily feed, kg	1.26	1.26	1.29	1.37	1.28	1.27
Average gain/feed[c]	.360[1,2]	.339[1]	.377[2,3]	.409[3]	.396[2,3]	.408[3]
Total trial period[d]						
Average daily gain, kg	.64	.66	.70	.74	.69	.69
Average daily feed, kg	2.09	2.19	2.24	2.25	2.13	2.11
Average gain/feed	.307	.300	.313	.328	.324	.330
Carcass measurements[e]						
Average carcass wt., kg	71	73	73	73	74	74
Average backfat, cm	2.82	3.07	2.84	2.84	2.59	2.67
Average loin-eye area, sq. cm	26.9	28.1	28.1	25.6	28.7	28.1
Average carcass length, cm	76.7	77.5	81.0	78.2	80.3	80.0

[a]Dietary crude protein was reduced by two percentage points (.18% lysine) at 50 kg.

[b]Each value is an average for one pen of 11 pigs in replicate 1, one pen of eight pigs in replicate 2.

Footnotes continued on next page.

[c]Values with different superscripts differ ($P<.05$).

[d]Replicate 1, 97 days; replicate 2, 112 days.

[e]Each value is an average for four carcasses.

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December, 1982 1982-2
University of Illinois at Urbana-Champaign
College of Agriculture Agricultural Experiment Station
Cooperative Extension Service Department of Animal Science

Sunflower Seeds in Diets for Young Pigs

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Sunflower seeds are the second most popular oil seed crop in the world, and approximately four million acres were planted to sunflowers in the United States in 1980 (Beard, 1981). They contain, on the average, about 40% oil, 20% protein and .70% lysine, and have about 29% fiber, primarily the hull fraction. In contrast to soybeans, they do not require heating before use in swine diets. They grind and mix readily with other standard swine diet ingredients. Thus, sunflower seeds are a potential source of supplemental fat (oil) for swine diets.

Only a few reports of the use of sunflower seeds in diets for growing-finishing swine have been reported (Laudert and Allee, 1974; Baird, 1980; Kepler et al., 1981). The studies reported here were initial investigations into the utilization of sunflower seeds by the young pig.

EXPERIMENTAL PROCEDURES

Two trials were conducted. In Trial I, 70 pigs averaging about 13 kg were used, and were on test for 26 days. They were confined in totally slotted floor pens in an environmentally regulated building. Feed and water were available at all times. In Trial II, 140 pigs averaging about 15 kg were used. They were confined to partially slotted floor pens in an environmentally regulated building. They were on test for 21 days. The diets were of the same composition as in Trial I, but were fed in both meal and pellet forms to determine whether pelleting would affect acceptance and utilization of the diets. Composition of the diets is shown in table 1. Graded levels of sunflower seeds to provide 0, 2.66, 5.33 and 10.66% levels of added dietary fat were fed. In Diet 5, synthetic lysine was added to provide a calorie:lysine ratio comparable to the corn-soybean meal control diet. Diets 1 through 4 were formulated to be isolysine. Because of the high fiber content of sunflower seeds, dietary fiber increased with increasing dietary levels of sunflower seeds.

RESULTS

Performance data from Trial 1 are shown in table 2. Although daily gain and daily feed values were lowest with the highest level of sunflower seeds, gain/feed

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values with the different levels of sunflower seeds were equal to or slightly better than that with the control diet (Diet 1).

The results of Trial II are shown in table 3. The 13 and 26% dietary levels of sunflower seeds significantly depressed daily gain (P<.05) and the 26% level depressed daily feed intake (P<.05) compared to the control diet. The average gain/feed value for the sunflower seed diets was higher than the value for the control diet. Pigs fed the pelleted diets gained faster (P<.05) and had higher (P<.05) gain/feed values than the pigs fed the meal diets. However, feed intake was not significantly affected. On the average, the improvement in gain/feed with the sunflower seed diets from pelleting was greater than for the control corn-soybean meal diet. This perhaps indicates that the heat and pressure of the pelleting process modified the crude fiber or energy availability or both.

The addition of synthetic lysine to the diet containing 26% sunflower seeds did not significantly affect its feeding value.

SUMMARY

Diets containing levels of 0, 6.5, 13.0 and 26.0% sunflower seeds were fed to four-week-old pigs. Trial I was of 26 days duration, Trial II, 21 days.

In Trial I daily gain and daily feed intake were depressed when the diet contained 26% sunflower seeds. Gain/feed, however, was not depressed, and when lysine was added to the diet there was a slightly higher gain/feed value.

In Trial II, pelleted diets resulted in faster gains (P<.05) and higher gain/feed values (P<.001) than did the meal diets. As in Trial I, feed intake was depressed with the 26% dietary level of sunflower seeds, but average gain/feed value for all sunflower seed diets was higher than for the control diet.

These data suggest that sunflower seeds can be used as a source of supplemental fat in swine rations, but for the young pig the high fiber content would limit the level used.

Table 1. Composition of Diets

Diet Number	1	2	3	4	5
Ground yellow corn	66.7	62.0	57.2	47.70	47.53
Solvent soybean meal	30.0	28.2	26.5	23.00	23.00
Sunflower seeds	-	6.5	13.0	26.00	26.00
Defluorinated rock phosphate	1.5	1.5	1.5	1.5	1.50
Ground limestone	1.0	1.0	1.0	1.0	1.0
TM salt	.35	.35	.35	.35	.35
Vitamin-antibiotic mix	.45	.45	.45	.45	.45
Lysine (78% L)	-	-	-	-	.17
	100.00	100.00	100.00	100.00	100.00
Calculated[a]					
Crude protein, %	20.4	20.6	20.7	21.0	21.0
Lysine, %	1.06	1.07	1.07	1.09	1.23
Crude fiber, %	2.90	4.59	6.28	9.66	9.66
Fat, %	2.20	4.67	7.01	11.68	11.68

Table continued on next page

Calculated[a] (cont'd)	1	2	3	4	5
kcal/lb, G. E.	1744	1812	1880	2016	2016
kcal/% lysine	1645	1693	1757	1850	1645

[a]Values assumed:	Crude protein, %	Lysine, %	Fat, %	kcal/lb[b]	Crude fiber, %
Corn	8.8	.24	3.5	1760	3
Soybean meal	48.5	3.00[b]	-	1900	7
Sunflower seeds	21.0	.71[b]	41.0	2769	29

[b]Assay values.

Table 2. Summary of Results of Trial 1

Sunflower seeds, %	0	6.5	13.0	26.0	26.0
Added lysine	-	-	-	-	+
Average initial weight, kg[a]	13.3	12.9	13.3	12.8	13.3
Average daily gain, kg[b]	.61	.63	.63	.55	.56
Average daily feed, kg[b]	1.15	1.16	1.18	1.03	1.04
Average gain/feed[b]	.534	.550	.535	.539	.544

[a]Each value is an average for two pens of seven pigs each fed for 26 days.

[b]Differences among dietary treatments were not significant.

Table 3. Summary of Results of Trial II

Sunflower seeds, %	0	6.5	13.0	26.0	26.0	
Lysine added	-	-	-	-	+	
Average initial wt., kg[a]						Avg.
Meal diet	15.4	15.8	15.6	15.3	15.1	15.4
Pellet diet	15.6	16.1	15.8	15.2	15.2	15.6
Average	15.7	15.9	15.7	15.3	15.4	
Average daily gain, kg						
Meal diet	.62	.64	.55	.59	.57	.60
Pellet diet	.65	.68	.65	.60	.59	.64[b]
Average[c]	.64[1]	.66[1]	.60[2]	.60[2]	.58[2]	
Average daily feed, kg						
Meal diet	1.29	1.29	1.16	1.19	1.16	1.22
Pellet diet	1.31	1.27	1.30	1.14	1.09	1.22
Average[c]	1.30[1]	1.28[1]	1.24[1,2]	1.16[2]	1.13[2]	
Average gain/feed						
Meal diet	.484	.495	.474	.497	.492	.488
Pellet diet	.503	.538	.514	.528	.542	.525[d]
Average[c]	.493[1]	.517[2]	.494[1]	.512[1,2]	.517[2]	

[a]Each value is an average for two pens of seven pigs each, on test for 21 days.

Footnotes continued on next page.

[b]Pigs fed pelleted diets gained significantly ($P<.01$) faster than those fed meal diets.

[c]Values with different superscripts differ ($P<.05$).

[d]Pigs fed pelleted diets had significantly higher ($P<.001$) gain/feed values than those fed meal diets.

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December, 1982 1982-3
University of Illinois at Urbana-Champaign
College of Agriculture Agricultural Experiment Station
Cooperative Extension Service Department of Animal Science

Why Don't All Pregnant Gilts Go to Term?

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There are many possible causes for failure of pregnancy. When one considers all the things that can go wrong, it is perhaps a wonder that any pregnancy produces live piglets. At the very first a normal embryo must be produced from the joining of a normal sperm and egg. Not all sperm and eggs contain a complete set of instructions in the form of genetic material for the development of a fully formed fetus. In some cases, there are gaps in the genetic information. Sometimes chromosome numbers are abnormal due to improper divisions during formation of eggs or sperm. More than one sperm may occasionally penetrate the egg giving the egg a double dose of the male contribution which leads to faulty development and invariably death. Normal embryos may have only one mother and one father. Each male has an innate proportion of normal sperm, plus the proportion may be influenced by toxins in the diet or environment or by a rise in testicular temperature due to fever or weather.

Once fertilization has occurred, the hazards are somewhat different. It is biologically and financially uneconomical for a gilt to carry a litter of three or four fetuses through an entire gestation period. Pigs have evolved a mechanism for reducing the chances of such a small litter. If by day 12 of gestation each of the long uterine horns are not completely occupied by growing embryos, the pregnancy will be lost. Therefore, a litter of 4 or less embryos is lost as is a litter of embryos that is not evenly distributed throughout the long uterine horns.

Each mother and fetus have complex blood types which have immunological effects. Incompatibilities between the mother and fetus can reduce the proportion of pregnancies carried to term and the size of some litters that do go to term.

Certain components of the diet, a high plane of nutrition and certain aspects of the environment can influence the level of hormones. These effects are by either affecting the production or metabolism of steroid hormones essential to maintenance of pregnancy. A very high protein content, a high caloric intake, high levels of antibiotics and exposure to environmental toxins such as insecticides, herbicides and fungicides can all influence levels of steroid hormones. Toxins arising from molds on feeds and other sources may have a direct adverse effect on the fetus. High levels of aflatoxins and zearalarone from moldy corn can have a profound impact on the course of a gestation in pigs. One of the

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deceptive aspects of the effects of toxins is the lack of real obvious signs that something may be wrong. There is rarely an abortion nor does the gilt return to heat even though there may not be any live embryos or a pregnancy at all. The effect of the zearalarone mimics a pregnancy thus lulling the breeder into a sense of complacency until farrowing time. Somewhat the same symptoms characterize the effect of viral diseases incurred during gestation. A common accounting goes like this: My gilts were mated, checked out pregnant at 40 or 50 days of gestation, did not return to heat, did not cast off any fetuses or membranes but did not appear pregnant at about 90 to 100 days and did not farrow. The mechanism for maintenance of pregnancy in the pig is such that once the gilt is pregnant at about 25 to 30 days she will usually remain pregnant or pseudopregnant and not return to heat for 60 to 80 days even though all fetuses are dead and are resorbed. Pseudorabies and parvoviruses seem to be among the several conditions that cause fetal death with subsequent pseudopregnancy. Thus genetics, management, diet, environment, toxins and disease all can keep pregnancies from going to term.

December, 1982 1982-4
University of Illinois at Urbana-Champaign
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Inducing Farrowing by Using Prostaglandin

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Effective and efficient use of management time in the farrowing house could be markedly improved if time and duration of parturition could be controlled. Surveillance of all the parturient sows would be feasible and should result in greater piglet survival to weaning.

In early studies, compounds known as clucocorticoids were used to initiate parturition. However, results were not encouraging. More recently, a class of compounds known as prostaglandins has been considered. They can effectively terminate pregnancy without apparent serious side effects (Cerne and Jochle, 1981; Diehl et al., 1974).

The objectives of this study were to evaluate the effectiveness of a synthetic prostaglandin, Alfaprostol®, in controlling time of parturition and on piglet survival.

Ninety-eight sows in seven different groups were used. All sows within each group were hand-mated within a 7-day period and were assigned to one of five treatment groups just prior to entering the farrowing facility. Treatment groups were sows receiving 0.0, .5, 1.0, 2.0 or 3.0 mg of the compound by intramuscular injection. Injections were administered between 1100 and 1200 hours on day 111, 112 or 113 of gestation. Control sows receiving 0.0 mg of the compound were allowed to farrow at random. Needed assistance was given to any sow during the normal working hours of 0700 to 1600 hours daily.

Farrowings which occurred during normal working hours, 0700 to 1600, were differentiated from those occurring outside of normal working hours. Duration of the actual process of farrowing was also recorded. The interval from day 114 of gestation to onset of parturition was recorded for control sows. The interval from receiving an injection to onset of parturition was recorded for sows in the treatment groups. Records were kept on total and stillborn piglets per litter.

Preliminary data indicate that about 63% of the sows in all groups farrowed during normal working hours. Of the treated sows, 88.8% farrowed within 36 hours of receiving an injection, with average intervals from injection to farrowing ranging from 26.85 hours to 37.08 hours for the different treatments. For the control sows, the average time from day 114 to farrowing was 29.90 hours, with a range from 101 hours before day 114 to 85 hours after day 114.

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Numbers of piglets born and numbers of stillborn piglets per litter were similar in all groups. Occurrence of stillborn piglets does not appear to be due to the treatments. Most of the stillbirths were associated with prolonged labor periods of 5 to 11 hours. Some studies have indicated that stillbirth rate may be significantly reduced with the induction of parturition (Cerne and Joshle, 1981).

Effects of prostaglandin on farrowing performance of sows

Item	Treatment group Alfaprostol, mg[a] 0.0	0.5	1.0	2.0	3.0
Number of sows	18	20	20	20	20
Farrowing time					
0700-1600 hrs	11	13	12	12	14
1600-0700 hrs	7	7	8	8	6
Treatment to farrowing, hrs	29.9[b]	37.1	33.5	26.9	30.0
Farrowing period, hrs	3.3±1.2	3.6±1.4	3.3±1.1	3.9±1.5	4.0±2.5
Pigs born/litter[c]	11.7	10.9	10.8	10.8	11.4
Stillborn pigs/litter	.78	.75	.85	1.00	.70

[a]Injected on day 111, 112 or 113 of gestation.

[b]Day 114 of gestation to farrowing, hours.

[c]Excluding mummies.

The farrowing periods were all very similar, with the average length being 3 to 4 hours, indicating that the treatments had no adverse effects on the length of the process of farrowing. Day of injection, whether 111, 112 or 113, did not appear to have any significant effect on time from injection to onset of parturition or stillbirth rate.

As a result of this study, it appears that about 90% of treated sows would farrow within 36 to 48 hours after receiving prostaglandin. This has important implications for the swine industry. Labor could be utilized more efficiently, stillbirth rate could be reduced, and pig survival could be increased if sows were expected to farrow in a fairly short, predetermined time period.

Uniformity of pigs would be improved since litters would be very similar in age, allowing for greater efficiency of cross fostering. Facilitation of weaning and sow management would be additional advantages of greater pig uniformity, thus promoting the use of an all-in, all-out concept. Weekend farrowing could be eliminated and systems established to farrow, for example, two days a week.

However, this type of program would require very close management. To derive the greatest benefit from an induced farrowing program the sows should be bred as close to the same time as possible. The exact breeding date of the sow must be known; as has been shown by injection of prostaglandin prior to day 110, very poor piglet survival is the result (Kraeling and Rampacek). Since exact breeding dates are not usually known when pen or pasture breeding systems are used, prostaglandin cannot be used to induce farrowing in these situations.

The product used in these trials is being used on an experimental basis and is not available for commercial use at present. However, these data are part of a large study being conducted at several research institutions for the purpose of gaining FDA clearance for use of the compound in parturition control in pregnant swine.

ACKNOWLEDGEMENTS

Alfaprostol® (RO 22-9000). This study was supported in part by a grant from Hoffmann-LaRoche, Nutley, New Jersey.

Thanks go to the staff at the Moorman Animal Breeding Research Farm, especially Tom Park and Bob Gilbert, for their cooperation and assistance in this study.

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December, 1982 1982-5
University of Illinois at Urbana-Champaign
College of Agriculture Agricultural Experiment Station
Cooperative Extension Service Department of Animal Science

Effect of Dietary Level of Alfalfa Hay and of Lasalocid on Performance of Growing-Finishing Swine

D.P. HOLZGRAEFE, J.D. TRACY, AND A.H. JENSEN

As the demand for feed grains for human use increases, alternative energy feedstuffs will be used increasingly for livestock production. Such feeds include forages and fibrous by-products. Much of the work evaluating the ability of swine to utilize forages has been conducted using growing-finishing pigs. It appears that the lower metabolizable energy of forages for swine has been a major hindrance to incorporation of these feedstuffs into practical swine diets. The inhibitory effect of high levels of dietary fiber on growth rate and feed efficiency of growing-finishing swine has been reported (Crampton et al., 1954; Teague and Hanson, 1954; Jensen et al., 1959; Larsen and Oldfield, 1961). This growth depression results from a marked reduction in dry matter digestibility and nitrogen-free extract and crude protein utilization. The contribution of forages to swine energy requirements varies from 5 to 28% according to Friend et al. (1964), Farrell and Johnson (1972) and Imoto and Namioka (1978), and depends on the quantity of fermentable carbohydrate reaching the lower gastrointestinal tract.

Ionophores, or polyether coccidiostats, have improved the feed efficiency of ruminants by increasing energy utilization in concentrate and roughage diets. This paper supports that an ionophore improves feed efficiency of swine.

EXPERIMENTAL PROCEDURE

One hundred ninety-two crossbred pigs were randomly assigned to six dietary treatments with eight pigs per pen and four replications of each treatment. Experimental treatments are outlined in Table 1. All diets were fed ad libitum and the pigs had ad libitum access to nipple waterers. Pigs were housed in a partially slotted concrete floor building. Average initial pig weight was approximately 28 kg and they were on test until 91 kg. Pigs were weighed every 28 days. Data collected were analyzed according to Duncan's Multiple Range Test (Table 1).

EXPERIMENTAL RESULTS

Pig performance data during the growing-finishing periods are shown in Table 2. Pigs consuming corn-soybean meal diets gained significantly ($P<.05$) more per day and more efficiently than those fed corn-alfalfa hay diets. These results were

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consistent throughout the trial. Lasalocid (30 g/ton in the corn-soybean meal diet, 30 and 100 g/ton in the corn-alfalfa hay diets) appeared to improve pig average daily gain and feed efficiency.

These data support that lasalocid improves feed efficiency of growing-finishing pigs. Additional work is necessary to quantify this response and identify specific modes of action of this compound in swine nutrition.

Table 1. Composition of Diets

Ingredient	Diet Number 1	2	3	4	5	6
Ground yellow corn	78.55	56.55	56.45	56.25	55.55	78.25
Ground alfalfa hay	-	25.00	25.00	25.00	25.00	-
Soybean meal (48%)	19.00	16.00	16.00	16.00	16.00	19.00
Defl. rock phosphate	1.25	1.25	1.25	1.25	1.25	1.25
Ground limestone	0.75	0.75	0.75	0.75	0.75	0.75
Trace mineralized salt[a]	0.35	0.35	0.35	0.35	0.35	0.35
Illini vitamin mix[b]	0.10	0.10	0 10	0.10	0.10	0.10
Lasalocid premix[c]	-	-	0.10	0.30	1.00	0.30
	100.00	100.00	100.00	100.00	100.00	100.00
Calculated %						
Crude protein[d]	16.20	17.00	17.00	17.00	17.00	16.20
Lysine	.76	.77	.77	.77	.77	.76
Calcium	.73	.80	.80	.80	.80	.73
Phosphorus	.55	.54	.54	.54	.54	.55
NDF[e]	9.70	20.00	20.00	20.00	20.00	9.70

[a]Contains in %: Fe, 2.86; Cu, .229; Mn, .571; Zn, 2.86; I, .01: Se, .00286 and salt, 80.0.

[b]Contains per kg: 3.3 M IU vitamin A; .33 M IU vitamin D_3; 22,000 IU vitamin E; 1.1 g riboflavin; 16.5 g niacin; 6.6 g calcium pantothenate; 165 g choline chloride and 17.6 mg vitamin B_{12}.

[c]Contains 5 g of lasalocid per pound.

[d]Crude protein level was reduced two percentage points when pigs weighed 50 kg.

[e]Neutral Detergent Fiber.

Table 2. Summary of Averages of Daily Gain, Daily Feed and Gain/Feed

Diet No.	1[a]	2	3	4	5	6[a]
Alfalfa hay, %	0	25	25	25	25	0
Lasalocid, g/ton	0	0	10	30	100	30
Average initial wt., kg	28	28	28	28	28	28
Average daily gain, kg						
Start to 45 kg	.71	.50	.47	.50	.52	.74
45 to 68 kg	.84	.65	.68	.70	.72	.85
68 to 91 kg	.87	.73	.72	.73	.77	.92
Start to 91 kg[c]	.81[1]	.64[2]	.64[2]	.65[2]	.67[2]	.84[1]
Average daily feed, kg						
Start to 45 kg	2.09	1.68	1.81	1.73	1.74	2.04
45 to 68 kg	2.77	2.85	3.07	2.75	2.87	2.85
68 to 91 kg	3.17	3.59	3.33	3.35	3.43	2.93
Start to 91 kg	2.67	2.81	2.83	2.73	2.79	2.60
Average gain/feed						
Start to 45 kg	.346	.300	.265	.294	.303	.362
45 to 68 kg	.306	.232	.227	.256	.229	.304
68 to 91 kg	.280	.207	.217	.218	.227	.316
Start to 91 kg[c]	.305[1]	.228[2]	.229[2]	.241[2]	.240[2]	.323[1]

[a]Diets 1 and 6 were corn-soybean meal diets.

[b]Each value is an average for four pens of eight pigs each.

[c]Numbers within a row with different superscripts differ significantly ($P<.05$).

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December, 1982 1982-6

University of Illinois at Urbana-Champaign

College of Agriculture Agricultural Experiment Station

Cooperative Extension Service Department of Animal Science

Gestation Environment Alternatives

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Animal-welfare activists have expressed concerns about several modern swine-production techniques. Perhaps none is more intense than that about the practice of holding pregnant sows and gilts in gestation crates. They believe animals kept in this way are being deprived of required environmental stimulation.

But there are sound reasons for the popularity of gestation crates among pork producers. Several of these reasons have to do directly with animal welfare: the gestation crate permits a level of individualization of care and feeding rarely achieved in group situations, and it practically eliminates fighting among sows. Further, the gestation crate requires less floor space per animal than must be allowed in group systems.

The fact remains, however, that neither is there scientific evidence upon which to base a rigorous refutation of any claim that the gestation-crate environment unnecessarily deprives the pregnant gilts or sow of needed stimuli. No detailed comparative studies have been made, and thus we do not have quantitative knowledge of the behavior and function of pregnant swine kept in different systems of gestation environment.

Is the behavior of gilts and sows kept in gestation crates radically different from that of those grouped in pens? What are the pros and cons of both systems? Can we devise modifications of the respective systems such that pregnant gilts and sows are under less stress than when kept in more conventionally designed facilities? Are there truly more humane alternatives as judged by behavioral and functional criteria? If so, in all likelihood they should also enhance the rate and efficiency of productive and reproductive performance.

The purpose of this study was to compare reproductive performance and overt behavior of pregnant gilts held in one of five gestation environments from one to four days after mating until 24 to 27 days after mating. With one exception, these environments typified the variety of pen and crate designs used by pork producers today. As listed, opportunities for social contact and movement go from more to less:

1. open pen with one feeding trough,
2. open pen with feeding stalls,
3. newly designed 22-inch-wide gestation crate with flare at one end

which allows a gilt or sow to turn around at will,
4. standard 22-inch-wide gestation crate, and
5. 22-inch-wide gestation crate with solid partitions.

An animal's productive and reproductive performances have long been considered to be reliable, objective measures of its well-being. If an animal's needs are met, according to this theory, it performs up to standard. Average daily gain was one such performance measure compared among the five environments. Conception rate was another. Considering that porcine embryos implant between 7 and 10 days after mating, it is possible that conception rate could have been affected by gestation environment.

The number of live embryos present after roughly one month of gestation was also compared among the five environments. It is before this 30-day point that a drop in reproductive efficiency may be attributed to effects of the social or physical environment to which the pregnant gilt has been exposed.

An animal is able to make behavioral adjustments to its environment, so quantification of well-defined behaviors might be used to assess environmental effects upon that animal. Behavioral variations among the five environments might indicate interference with the animals' well-being in one environment or another. The behavioral data summarized for this experiment were percentage portions of time spent lying, standing, eating, drinking, and fighting, respectively.

Data were collected on 113 gilts in six trials. They are summarized in the table, following which are listed salient aspects of the results.

Table 1. Results of the Experiment

	Treatment				
Variable^{a}	1	2	3	4	5
Avg. daily gain (kg)	0.56	0.46	0.48	0.49	0.49
Conception rate (%)	95.0^{c}	80.0^{b}	90.0^{c}	100.0^{c}	85.0^{c}
Avg. no. live embryos	11.3	11.9	11.5	12.1	11.6
Aggression time (%)	2.0^{d}	8.0^{e}	---	0.5^{d}	---
Lying time (%)	85.0^{e}	86.0^{e}	86.0^{e}	81.0^{d}	86.0^{e}
Eating time (%)	4.1^{d}	4.4^{de}	5.7^{f}	5.2^{ef}	5.6^{f}
Drinking time (%)	0.4^{f}	0.6^{e}	0.5^{ef}	1.5^{d}	0.6^{e}

^{a}Values are treatment averages based on five trials for reproductive data and four trials for behavioral data.

^{b,c}Values on the same line with different subscripts differ at the .12 level of probability.

^{d,e,f}Values on the same line with different subscripts differ at the .01 level of probability.

#The five environments in which the gilts were held did not significantly influence average daily gain during the first four weeks of gestation.

#Conception rate varied considerably among environments. It was highest for gilts held in the standard gestation crates, lowest in the open-pen/feeding-stall arrangement, and this difference was statistically significant at the .12 level.

#No environment was found to significantly affect the number of live embryos present one month after mating.

#The early gestation environment did affect the amount of fighting among animals which occurred. Gilts in the open pen with feeding stalls spend considerably more time fighting than did those in any other environment.

#Gilts in the standard gestation crates spent slightly, but significantly, less time lying, and thus more time standing, than did gilts in any other environment.

#Eating time was shorter for gilts in the two open pens than for those in any of the crate arrangements.

#Gilts in the standard gestation crates spent about three times as much time with their noses at the nipple waterer than did those in any other environment.

From these results we can conclude that, when different gestation environments were compared using widely accepted performance, functional, and behavioral parameters, no one system stood out as being better or worse for supporting an animal's well-being. In particular, the standard gestation crate seems to have provided well for the gilts' physical and social needs. For instance, on the basis of conception rate, gilts in the standard crate outperformed those in the open pen with feeding stalls by 20 percent. This might have been due in part to the vast difference between these two environments in fighting which occurred during the first few days after group formation. The small behavioral differences observed between gilts in the gestation crate and those in other environments probably reflect the animals' attempts to adapt to differences inherent in the designs of the different holding systems, and probably are not the result of excessive stress.

The research reported in this Research Progress Report was funded in part by the National Pork Producers Council.

December, 1982 1982-7
University of Illinois at Urbana-Champaign
College of Agriculture Agricultural Experiment Station
Cooperative Extension Service Department of Animal Science

Studies of Carbon Monoxide Toxicosis in Swine

G.L. MORRIS, S.E. CURTIS, AND J. SIMON

Confinement rearing of swine has resulted in environmental problems unique to that system of animal production. One of the major problem areas is that of toxic gases that the animal may encounter. The problem becomes most evident in wintertime management of confinement swine production houses because of reduced ventilation rates. The price of keeping an animal house warm in winter is steadily increasing. This has caused many producers to reduce ventilation rates below critical levels, resulting in improperly ventilated buildings. Also, new waste management practices that remove the waste frequently allow the producer to reduce ventilation rates even more. When the ventilation rate is reduced in swine houses heated by malfunctioning or improperly vented heaters there can be an increase in the carbon monoxide (CO) concentration above safe limits.

Carbon monoxide is an imperceptible poisonous gas produced by incomplete combustion of hydrocarbon fuels. There are two sources of CO in the body: endogenous, from the breakdown of hemoglobin and other heme-containing pigments, and exogenous, from inhalation. The poisonous nature of CO results from the strength of the coordination bond formed with the iron atom of hemoglobin, resulting in the formation of carboxyhemoglobin (COHb) (Antonini, 1967).

Several field case reports have indicated a correlation between an increased incidence of stillborn full-term piglets and elevated atmospheric CO levels (Carson et al., 1980; Carson and Donham, 1978; Castryck and Debruyckege, 1979; Kellee, 1976; Wood, 1979). The stillbirths occurred after the placement of near-term sows into a supplementally heated farrowing house. Further investigation revealed that the CO concentration in each of the environments was elevated. The CO concentration recorded ranged from a low of 120 ppm to a high of 200 ppm in these field cases. There were no infectious causes found which could have resulted in the stillbirths. Poor maintenance of the gas-fired heaters was evident in most of the cases reported (Carson and Donham, 1978; Castryck and Debruyckere, 1979; Wood, 1979).

Dominick(1982) found a linear relationship between blood COHb concentration in near-term miniature sows and atmospheric CO concentration over the range of 150 to 350 ppm. This work also revealed a strong correlation between maternal COHb concentrations and the incidence of stillbirths in the litter. Dominick (1982) reported a critical level of 23% maternal COHb saturation, above which frequency of stillborn piglets is increased significantly. This concentration corresponds to an atmospheric CO concentration of 250 ppm.

Novy et al. (1973) found that in swine fetal hemoglobin has a higher affinity for oxygen than does maternal hemoglobin, but that the hemoglobin moiety is identical in sows and their fetuses. The increased affinity of the fetal hemoglobin for oxygen seems to be due to a lower concentration of 2,3-diphosphoglycerate in the red blood cells. As one might predict, the stronger binding affinity of fetal hemoglobin follows for CO, as well (Dominick, 1982).

Behavior plays a large role in the newborn piglet's ability to survive. The piglet must be able to seek out and find a teat and to compete with its littermates for the teat soon after birth. Randall (1971) developed a method of individual clinical assessment to evaluate a piglet's viability at birth. He concluded that a large proportion of the mortality and reduced viability at the time of delivery could be attributed to intra-uterine asphyxiation. DeRoth and Downie (1976) found that an attempt to stand by the piglet was a good indicator of the piglet's viability. A piglet's ability to stand is in most circumstances a prerequisite for nursing, therefore time to nurse should also be an important indicator of a piglet's viability. Fechter and Annau (1980) used a negative geotaxis behavior test on neonates to assess the effects of CO on prenatal exposure of gravid rats. They found that pups delivered by dams exposed to CO had a lower success rate on this test.

The brain is one of the organs most sensitive to hypoxia. Because of the tremendous amounts of oxygen required by the brain it is usually the organ first affected by CO-induced hypoxia. Dominick (1982) reported that full-term piglets, whose dams had been exposed to 300 ppm CO late term, showed focal leukoencephalomalacia and spongiosus, astrocytic and microglial proliferation, multifocal petechial hemorrhages, and changes suggestive of myeline degeneration in the cortical white matter, brainstem, and cerebellum.

T. L. Carson of Iowa State University has measured atmospheric CO concentrations as high as 150 ppm in closed pig nurseries during cold weather. He has not noticed negative effects of such exposure on the animals' health or performance, but he has suggested that controlled studies be conducted at the University of Illinois.

The studies we are in the process of conducting are designed to ascertain effects on fetuses and neonates of exposure of late-term pregnant gilts to CO at 200 ppm, and to determine the effects of CO at 200 ppm has on the weanling pig. Better knowledge of these relations hopefully will serve to improve our ability to manage farrowing house and nursery environments, making it possible to refine recommendations to pork producers.

SELECTED STUDIES IN PROGRESS

Study 1 - Blood Parameters in Neonatal Piglets from Gilts Exposed Late-Term to Carbon Monoxide at 200 ppm

On day 108 of gestation, gilts are placed in an air-pollutant exposure chamber. After a 12- to 24-hour adjustment period, a blood sample is taken from the anterior vena cava (Carle and Dewhirst, 1942; Hoerlein et al., 1951) and analyzed for total hemoglobin concentration, percent oxyhemoglobin, and percent carboxyhemoglobin. From this time on, CO is added to the chamber at a rate so as to achieve a concentration of 200 ppm in the gilt's environment. Twelve to 24 hours after CO exposure is started, another blood sample is taken and analyzed. Once daily the CO is turned off for a 15-minute period to allow for feeding and cleaning.

The gilt is observed for signs of onset of parturition. All farrowings are attended. At farrowing, every other piglet (half of piglets) born live is removed from the chamber via an air lock. A 3- to 5-ml sample of blood is obtained from the anterior vena cava. Two hours and again 24 hours after birth, the piglet is removed from the chamber again and a 3- to 5-ml sampled of blood obtained. Two hours after the last piglet is delivered, a blood sample is obtained from the dam by ear-vein puncture.

Throughout the study, untreated control litters are studied in the same manner as described from those exposed to elevated atmospheric CO concentration, except no additional CO is added to the chamber inlet air.

Study 2 - Behavioral Parameters in Piglets Exposed to Carbon Monoxide at 200 ppm Before and After Birth

The half of the piglets not used in Study 1 are used in the second study. Time of birth is recorded for each piglet, and each is observed continuously till its time to first nursing is determined. At 24 and 48 hours after birth, each of these piglets is removed from the chamber and subjected to two novel behavior tests. First, negative geotaxis is tested by placing the piglet on a 15°-inclined floor (plastic-coated expanded metal) with its head facing down the slope (Fechter and Annau, 1980). Time to turn the body at least 170° to face uphill is recorded. This is done three times in quick succession to yield an average time. A maximum time of three minutes is allowed to successfully complete the response each time.

Also, the piglet is exposed to an open-field test (Beilharz and Cox, 1967). A pen measuring 1.8 m on a side with solid white walls .46 m high is used. The concrete floor is marked off in square units of .09 m^2. Each piglet is placed in the center of the pen and observed for three minutes. The number of squares the piglet moves into and the pattern of movement is recorded.

Study 3 - Blood Parameters in Weanling Pigs Exposed to Carbon Monoxide at 0 and 200 ppm Concentrations

Blood parameters as studied in Study 1 are measured in four- to seven-week-old pigs exposed to carbon monoxide at either 0 or 200 ppm concentration. Eight pigs from each of two litters are assigned at random to inhalation toxicology chambers, each of which holds four littermate pigs. There is a five-day adjustment period after which a three-week study is conducted. Blood samples are drawn from the anterior vena cava of two pigs in each chamber on days 1, 10, and 21 of each trial.

Study 4 - Performance of Weanling Pigs Exposed to Carbon Monoxide at 0 and 200 ppm Concentrations

Average daily gain and feed-conversion ratios are determined for the pigs in each chamber, as described for Study 3 above.

RESULTS

Study 1

At birth, piglets from gilts exposed to 200 ppm CO have COHb saturation percentage higher than their dams--roughly 20% COHb saturation versus 15% for the dams. By two hours after birth COHb saturation of the piglet's blood has fallen to the dam's level or lower. The level remains the same or rises slightly until 24 hours postnatum.

In comparison to piglets from gilts exposed to 0 ppm CO, COHb saturation in piglets from exposed gilts is quite different--17% COHb saturation versus 0%.

Concentration of hemoglobin does not seem to differ between piglets from the two treatment groups.

Study 2

In the open-field test at 24 hours postnatum, control piglets moved 15% more than did piglets from gilts exposed to CO at 200 ppm (58 squares versus 49). By 48 hours, this difference had increased (54 squares versus 40).

The time required for 24-hour-old control and treatment piglets to turn 170° on the negative-geotaxis test floor was essentially the same (26 seconds versus 24), but by 48 hours the piglets from CO-exposed gilts took twice as long to make the 170° turn as did the control piglets (81 seconds versus 41).

The time required for piglets to start nursing does not seem to be affected by this treatment (43 minutes for control piglets versus 42 for exposed).

Study 3

A change in total hemoglobin concentration of weanling pigs exposed to CO at either 200 ppm or 0 ppm is observed by day 10 of a trial. Treatment pigs have 12.7 grams of hemoglobin per 100 ml of whole blood while controls have 11.5. By day 21 these levels have increased to 14.0 grams % for weanling pigs exposed to CO at 200 ppm versus 12.1 grams % for the control animals.

The percent COHb saturation in the weanling pig's blood stabilizes by 24 hours after exposure commences, remaining around 16% throughout a three-week trial. Carboxyhemoglobin saturation of control pigs is 0%.

Study 4

Average daily gain and feed-conversion ratio do not seem to be affected by exposing weanling pigs to carbon monoxide at 200 ppm. Exposed pigs gained .42 kg per day with a gain/feed ratio of .53, while the control animals gained .41 kg per day with a .52 gain/feed ratio.

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Effect of Copper Sulfate as a Growth Promoter

V.L. O'HEARN AND R.A. EASTER

INTRODUCTION

The trace mineral copper is required for hemoglobin formation and is also essential for various enzyme systems. The copper requirement of the 10 to 20 kg pig is reported to be 5 mg/kg of diet or 5 ppm (NRC, 1979). Numerous studies utilizing copper at high levels (250 ppm) have reported results varying from a negative response to an improvement in growth rate and feed efficiency (Braude, 1965; Hays and Kline, 1969; NRC-42, 1974; Conrad et al., 1970; Cromwell et al., 1978 and Stahly et al., 1981). There also appears to be an additive effect when copper is fed at 250 ppm in conjunction with an antibiotic (Cromwell et al., 1981).

PROCEDURE

Two feeding trials were conducted at the University of Illinois Swine Research Center. The first trial utilized 120 crossbred pigs with an average initial weight of 10.49 kg and the second trial utilized 100 crossbred pigs with an average initial weight of 8.14 kg. Pigs were allotted on the basis of litter, weight and sex to treatments. Trial 1 had six replicate pens per treatment with five pigs per pen, and Trial 2 had four replicate pens per treatment with five pigs per pen.

Diets are shown in Table 1. Each trial had four treatments: (1) 19% corn-soy control; (2) control + 250 ppm copper in the form of $CuSO_4 \cdot 5H_2O$; (3) control + ASP•250; (4) control + 250 ppm copper + ASP•250. Copper sulfate and ASP•250 were added to the diet at the expense of corn.

Table 1. Composition of Experimental Diets

Ingredient	Control	Copper sulfate	ASP•250	Copper sulfate + ASP•250
Ground corn	70.37	70.27	70.12	70.02
Soybean meal (48)	26.73	26.73	26.73	26.73
Def. rock phosphate	1.33	1.33	1.33	1.33

(Table 1 continued on next page)

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Table 1, Continued

Ingredient	Control	copper sulfate	ASP·250	Copper sulfate + ASP·250
Limestone	1.02	1.02	1.02	1.02
Trace mineral salt[a]	.35	.35	.35	.35
Illini vitamin mix[b]	.20	.20	.20	.20
$CuSO_4 \cdot 5H_2O$	---	.10	---	.10
ASP·250	---	---	.25	.25
	100.00	100.00	100.00	100.00
Calculated analysis				
% CP	19.02	19.02	19.00	19.00
% Lys	1.02	1.02	1.02	1.02
% Ca	.90	.90	.90	.90
% P	.60	.60	.60	.60
Cu (ppm)		250		250

[a]Contains the following in percent: selenium, .00286; iodine, .01; copper, .229; manganese, .57; iron, 2.57; zinc, 2.86; cobalt, .02 and sodium chloride, 78.0.

[b]Contains the following per lb of mix: vitamin A, 1,500,000 IU; vitamin D_3, 150,000 IU; vitamin E, 10,000 IU; riboflavin, 500 mg; d-pantothenic acid, 2.750 mg; niacin, 7,500 mg; choline chloride, 75,000 mg; vitamin B_{12}, 8 mg.

Pigs were housed in elevated nursery pens with solid partitions, nipple watering devices and expanded metal floors. Feed was offered ad libitum through galvanized steel self feeders.

Trials 1 and 2 were conducted for four weeks. Pigs were weighed at the start of the trial, after two weeks on trial, and at the end of the trial. Feed consumption was also recorded. Data were analyzed by analysis of variance techniques (Sokal and Rohlf, 1969), utilizing Statistical Analysis Systems (SAS)[1].

RESULTS

In the first feeding trial an error was made in the addition of copper sulfate ($CuSO_4 \cdot 5H_2O$) to the diet. Instead of 250 ppm, 500 ppm was added to the diet, a level which has been reported to be toxic to the pig (Bunch et al., 1962). Results of Trial 1 are shown in Table 2.

Table 2. Performance Data of Trial 1[a]

Diet	ADG, kg	ADF, kg	GF
Control	.51[c]	1.08[b]	.47[b]
Copper sulfate	.44[d]	.93[d]	.47[b]
ASP·250	.55[b]	1.15[b]	.48[b]
Copper sulfate + ASP·250	.49[c]	1.05[c]	.47[b]

(Footnotes on next page)

[1]Statistical Analysis Systems, the SAS Institute, Inc., Raleigh, North Carolina.

Table 2 Footnotes

[a]Values are means of six replicate pens.

[bcd]Means in a column with different superscripts are different (P<.05).

As is evident from the data, feeding copper at 500 ppm depressed growth rate and intake (P<.05). There was an improvement in growth rate and intake with the addition of ASP•250 to the control diet (P<.05). The addition of ASP•250 to the copper diet alleviated some of the toxic effect of copper. Average daily gain was not depressed as compared to the control and was improved over the ADG of pigs consuming the copper diet (P<.05). No differences were seen in feed efficiencies in this trial.

Four pigs consuming the copper diet were taken off test, one because of a bad leg and three because they were losing weight. One pig fed the copper + ASP•250 diet was also taken off test due to weight loss. One pig fed the control diet died, an autopsy was performed but revealed information not pertinent to treatment effects. The performance data from Trial 2 are shown in Table 3. There were no differences in ADG in this trial. The addition of 250 ppm copper depressed intake (P<.05) resulting in a numerically improved feed efficiency. In this trial there does not appear to be any additive effect of copper fed in combination with ASP•250. However, a large response to antibiotic is not expected in newer facilities. If copper functions in a manner similar to an antibiotic, a large response to the addition of 250 ppm copper would not be expected, either.

Table 3. Performance Data of Trial 2[a]

Diet	ADG, kg	ADF, kg	GF
Control	.45[b]	.90[bc]	.50[b]
Copper sulfate	.47[b]	.85[c]	.55[b]
ASP•250	.48[b]	.98[b]	.49[b]
Copper sulfate + ASP•250	.48[b]	.99[b]	.48[b]

[a]Values are means of four replicate pens.

[bc]Means in a column with different superscripts are different (P<.05).

CONCLUSIONS

The addition of copper at 500 ppm to a 19% corn-soy diet appears to be toxic. While no pigs consuming the diet died, intake and growth rate were depressed (P<.05). The addition of ASP•250 to the diet alleviated some of the toxicity, as performance of pigs consuming the copper + ASP•250 diet was equivalent to that of the controls. When copper was fed at 250 ppm there was no improvement in ADG; however, intake was depressed resulting in a numerically improved feed efficiency. When copper was fed at a non-toxic level (250 ppm), the addition of ASP•250 to the diet had no effect. The results of these two trials would indicate that while there are no detrimental effects from the addition of 250 ppm copper to the diet, there are no beneficial effects either when fed in newer facilities such as those at the University of Illinois Swine Research Center.

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December, 1982
1982-9
University of Illinois at Urbana-Champaign
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Improvement of Storage Life and Palatability of Pork Patties

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At the present time there is an increasing demand for a fresh ground pork by the consumer. As long as this demand exists, there is still the challenge for scientists in the meat industry to develop methods by which the product can be stored and remain stable with reduced rancid, off-flavor development for longer periods of time. Several spices and their oil extracts have been found to show antioxidant properties, thus decreasing the development of rancidity. Among these are rosemary and sage. On the other hand, a common ingredient of sausage products, salt, acts as a prooxidant, thus increasing development of rancidity. This project was designed to look at the effects of the spices alone and in combination with salt to determine if the spices can effectively impede the development of rancidity. Also effects of hot processing vs. conventional chilled processing on the development of rancidity was evaluated. Furthermore, effect of the fatty acid composition of pork fat was evaluated by using pork from pigs on three different diets.

EXPERIMENTAL PROCEDURE

The three diets are: a standard industry diet, a diet high in unsaturated fat and a high roughage diet of turf clippings. Half of each carcass was hot-boned and the other half chilled for 24 hours before boning.

The boneless pork is chopped, standardized to 20% fat, and reground into aliquots with the spice combinations called for in the experimental design. The samples are stored at -20°C for as long as 24 weeks, with chemical and sensory evaluations being conducted every two weeks.

Eight six-pound aliquots of the total mix were taken from both sides and the following treatments were applied:

1. Control - no salt or spice added
2. 1.5% salt
3. 1.5% salt and .19% sage
4. 1.5% salt and .1% rosemary
5. 1.5% salt, .1% rosemary and .19% sage
6. .19% sage and .1% rosemary
7. .1% rosemary
8. .19% sage

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Each of the six-pound aliquots were then further subdivided into 12 six-ounce samples. Each sample was wrapped and stored at a temperature of -20^{o}C for as long as 24 weeks.

Every two weeks the samples were analyzed by a six member sensory taste panel and by the thiobarbituric acid (TBA) chemical analysis to determine the levels of rancidity in the product.

RESULTS

The data in Table I shows that pork patties become significantly more rancid with storage at -20^{o}C. This table also indicates the animal diet has a significant effect on rancidity.

Table II shows the differences in the mean TBA values for the different spice treatments and hot vs. chilled processing. Spice treatments that contain salt had higher TBA values and addition of the spices lowered the TBA values. When the mean TBA values from the hot-boned process were compared to those from chilled process the mean values were significantly lower from the hot-boned product.

The results from these experiments indicate that as expected pork patty rancidity increases with storage time and the degrees of rancidity could be altered by the animal diet, adding spices to the product and the method of processing the product. This study will provide additional guidelines for increasing the storage life of ground pork.

Table I. Mean TBA Values for Diets and Time Periods[a]

Time in weeks	Mean TBA Values[b] Diet 1	Diet 2	Diet 3	F Value	Significance of F
2 weeks	.39	.41	.40		
4 weeks	.43	.47	.43		
6 weeks	.46	.51	.50		
8 weeks	.49	.56	.56		
10 weeks	.53	.61	.59		
12 weeks	.55	.65	.62		
14 weeks	.59	.68	.66		
16 weeks	.61	.72	.70		
18 weeks	.67	.76	.73		
20 weeks	.71	.80	.77		
22 weeks	.74	.86	.80		
24 weeks	.77	.88	.83		
Diet				180.480	.001
Time				504.275	.001

[a]N = 32

[b]TBA Value = mg of malonaldehyde per 1000g of meat

Table II. Mean TBA Values for Processing and Spice Treatments[a]

Spice Treatments	Mean TBA Values[b] Hot-boned	Chilled	F Value	Significance of F
No spice	.64	.67		
Salt	.66	.69		
Rosemary	.58	.60		
Rosemary and salt	.65	.64		
Sage	.57	.61		
Sage and salt	.57	.66		
Rosemary and sage	.59	.63		
Rosemary, sage and salt	.59	.62		
Process			12.647	.001
Spice Treatments			6.748	.001

[a]N = 72

[b]TBA Values = mg of malonaldehyde per 1000g of meat

December, 1982 1982-10
University of Illinois at Urbana-Champaign
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Slaughter Factors that Affect Pork Quality

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The physical appearance of fresh meat greatly influences the consumer acceptability of the product. Flavor, juiciness, and tenderness are perceived from fresh meat quality parameters such as color, firmness, and marbling in the lean. Consumer preference studies indicate that pale or dark colored pork cuts are much less desirable and that pale, soft low quality cuts are less tender and juicy with greater moisture loss during thawing and cooking (Topel et al., 1976).

Method of slaughter (dehairing versus skinning) as well as stunning method and procedure may influence pork quality. Some researchers have reported improved lean quality in skinned pork carcasses due to a faster chill rate compared to dehaired carcasses. Another condition that influences pork quality is ecchymosis (blood splashing). Blood splashing is caused by capillary rupture during the stunning to bleeding process. Blood spots in the lean may result in an unacceptable pork product for the consumer. Evidence suggests that use of an electrical stunner combined with a short interval from stunning to bleeding can reduce the incidence of blood splashing.

The objectives of this study were (1) to determine the effect of scalding and skinning on pork quality and (2) to determine the effect of time interval between stunning and bleeding on pork quality.

MATERIALS AND METHODS

Thirty-two Landrace sired crossbred barrows were selected from eight litters of market weight hogs, four hogs per litter. Animals within each litter were paired according to live weight with a maximum twenty pound (9.1 kg.) weight difference between paired hogs. One pair of littermates was randomly selected to be bled 15 seconds after stunning, while the remaining pair was bled 45 seconds after stunning. After bleeding, one carcass from each pair was scalded and dehaired and the other carcass was skinned. The experimental design is illustrated in Table 1.

Animals were shackled prior to stunning, stunned for ten seconds using a K. Schermer and Co. 110 volt (100 amp.) electrical stunner, hoisted immediately after stunning, and bled at the appropriate time interval. During the slaughtering process, the lungs were removed and subjectively scored for the presence of blood

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splash. Temperature decline and pH of the left side of each carcass was monitored at 45 minutes post-mortem and then two, four, six, twelve, and twenty-four hours after the initial measurement.

Table 1. Experimental Design

Bleeding Interval	Slaughter Procedure Scalded	Skinned
15 seconds	8	8
45 seconds	8	8

After 24 hours, the carcasses were ribbed between the 10th and 11th ribs and color, marbling and firmness of the loin eye were evaluated according to N.P.P.C. (1976) evaluation procedures. Two rib chops were removed from the loin between the 9th and 10th rib of the left side of each carcass and frozen at -40°C. The chops were used for expressible moisture and shear force tests.

RESULTS

Means and standard errors of quality traits for skinned versus scalded carcasses are presented in Table 2. Lean color score was significantly ($P < .05$) lower in the scalded pork carcasses compared to those skinned. The scalded carcasses may have had a lighter, paler colored lean due to a significantly ($P < .05$) higher initial chine temperature. A high post-mortem temperature accelerates muscle glycolysis and can result in a paler colored lean (Briskey and Wismer-Pedersen, 1961). The lean color values for the skinned carcasses were quite similar and were evaluated as possessing the "ideal" pork muscle color. Marbling scores for skinned carcasses were also higher, but the differences were not significant.

Lean firmness score was significantly ($P < .01$) higher for skinned carcasses and may be partially influenced by the slight post-mortem temperature advantage observed in the skinned carcasses.

Expressible moisture from the raw meat samples was significantly ($P < .01$) lower in the loin eye muscle from the skinned carcasses. This observation suggests that the firmer lean from skinned pork carcasses possessed a greater water holding capacity than the scalded carcasses. Percent moisture from raw meat samples was higher and raw percent free water was lower in skinned pork carcasses; however, both parameters were not significantly different. The superior values for raw expressible moisture and raw percent moisture along with the lower raw percent of free water values may result in less moisture loss during storage and thawing of the rib chops. Differences between the previously mentioned traits in cooked rib chops for the two procedures were not significant; however, the cooked pork chops from the skinned carcasses had a lower percent moisture during cooking and a higher percent moisture in the cooked product. A significant difference was not observed for Warner-Bratzler shear force values between the two procedures.

Means and standard errors for blood splash evaluation at 14 and 45 second bleeding intervals are presented in Table 3. No significant difference in number of blood splashes per 20 square inches of ham face and diameter of blood spots

Table 2. Means and Standard Errors of Quality Traits for Skinned and Scalded Pork Carcasses

Trait	Skinned	Scalded
Lean Color Score[a]	3.00 ± 0.00[d]	2.69 ± 0.12[e]
Marbling Score[a]	3.13 ± 0.22	2.69 ± 0.28
Lean Firmness Score[a]	3.19 ± 0.14[d]	2.50 ± 0.20[e]
Raw Expressible Moisture[b]	2.23 ± 0.05[d]	2.37 ± 0.30[e]
Raw Percent Moisture	75.27 ± 0.54	73.98 ± 0.61
Raw Percent Free Water	39.53 ± 0.78	41.58 ± 0.59
Percent Cooking Loss	32.13 ± 1.31	33.28 ± 0.96
Cooked Expressible Moisture	3.92 ± 0.21	3.63 ± 0.11
Cooked Percent Moisture	64.13 ± 0.92	62.89 ± 0.78
Cooked Percent Free Water	52.32 ± 1.88	50.31 ± 1.22
Warner Bratzler Shear[c]	10.13 ± 0.54	9.55 ± 0.49

[a]Based on the Wisconsin Pork Quality Standards:
Color: 1 = Pale, grayish white, 3 = grayish pink, 5 = dark red
Marbling: 1 = practically devoid, 3 = modest, 5 = abundant
Firmness: 1 = extremely soft and watery, 3 = moderately firm and dry, 5 = very firm and very dry.

[b]Ratio of total moist film area to meat film area.

[c]Pounds of shear force.

[de]Means in the same row with different superscripts are significantly different ($P < .05$).

Table 3. Means and Standard Errors for Blood Splash Traits at 15 and 45 Seconds Bleeding Intervals

Trait	15 Seconds	45 Seconds
Number of Blood Splashes per 20 in.^{2} of Ham Face	2.90 ± 0.65	3.74 ± 1.64
Splash Diameter, in.	0.055 ± 0.008	0.055 ± 0.010
Lung Splash Score[a]	2.78 ± 0.29	2.93 ± 0.26

[a]Lung splash score of 1 = no blood splash, 5 = severe blood splash.

were observed between the two intervals. These results suggest that electrically stunned hogs may be bled up to 45 seconds after stunning without significantly increasing the size and number of blood splashes observed in the ham lean.

Cooper and associates (1980) found a direct relationship between degree of lung hemorrhaging and incidence of capillary rupture in pork muscle. Mean lung splash scores for 15 and 45 second bleeding intervals were not significantly different. In addition, lung splash score and number of blood splashes per ham face did not vary for the two bleeding intervals. Results from this study do not support the use of lung blood splash as a prediction of blood splash in the ham face.

SUMMARY

Visual pork quality traits, especially lean color and firmness were significantly improved by skinning pork carcasses compared to the scalding technique. In addition, those traits associated with greater water holding capacity in fresh pork were superior in the skinned carcasses. On the other hand, palatability traits evaluated in the cooked rib chops were not improved in the skinned versus scalded pork carcasses.

The incidence of blood splash in the ham face was not increased when the bleeding interval was raised from 15 to 45 seconds after electrical stunning. Bleeding interval had no significant effect on visual pork quality or palatability traits.

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December, 1982 1982-11
University of Illinois at Urbana-Champaign
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Effects of Attending Farrowing

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Piglet mortality is the primary problem facing swine production today. This statement could have been made 25 years ago as well as today. The pork industry has made tremendous improvement in most phases of production technology, but not in piglet survival. Technical knowledge of how to increase the baby pig survival rate has been available for a long time, but it has not been fully adopted by the pork industry. An important reason for this is traditional acceptance of this loss as tolerable and an unavoidable part of the cost of producing swine.

What is the cost/benefit ratio for saving one more pig per litter? In the final analysis, each producer will need to determine this for himself. Saving more pigs' lives would be not only profitable, but is a reasonably easy pursuit. It is based on scientific knowledge of the nature of the piglet. More specifically, it is based on knowledge of the neonatal piglet, because two-thirds of the preweaning deaths of liveborn piglets occur during the first four days after farrowing. Strict attention to the piglets' needs during the newborn period is most likely to pay dividends. This indisputable fact makes it all the more ironic that many piglets do not have human eyes set on them before they are eight hours old.

The research reported here was designed to study the effects of attending farrowing on piglet survival rate.

Gravid females were washed with water and treated for external parasites, and then moved into 20-crate farrowing rooms on day 109 post-mating. The rooms previously had been emptied of waste, washed with cold water at high pressure, and fumigated with formaldehyde.

Thirty-six sows were allotted to treatment (22 farrowings unattended, 14 attended) together with 22 gilts (10 unattended, 12 attended). When a piglet was born in an attended litter, its mouth, trachea, and nostrils were cleared of fluids with a rubber ear syringe. If the piglet was not breathing, the mouth and snout areas were wiped and mouth-to-mouth resuscitation attempted until revival or evidence that the piglet was not going to breathe. The umbilicus was grasped and pulled free if it had not already ruptured. The piglet was then dried with paper towels. After drying, the umbilicus was tied with string two inches from the body and severed with needle-teeth pliers and dipped in a 2% iodine solution.

Any spraddle-legged piglets were treated at this time by taping its legs together with adhesive tape. Piglets were placed at the sow's udder and assisted in suckling until it was evident that colostrum had been consumed. A heat lamp was present in the crates and was moved as necessary to be above the nursing piglets. If a piglet weighed less than 1 kilogram (2.2 pounds) at birth, it received 15 ml of colostrum via a plastic syringe and then 15 to 25 ml of a commercial milk replacer four times daily for three days. A sow was given assistance while farrowing by administering 2 cc of oxytocin if the time between piglets was greater than 60 minutes. If a piglet was not born in the next 30 minutes after oxytocin administration, obstetrical assistance was provided. The attendant thoroughly washed both arms with surgical soap, rinsed, and then lathered again, leaving soap on the arm that entered the sow to serve as lubricant. If piglets were stillborn or were weak with a ruptured umbilicus, the attendant became more liberal with administering oxytocin and providing obstetrical assistance. Any farrowing female obtaining obstetrical assistance received 10 cc of penicillin intramuscularly at the end of the farrowing and then again 12 and 24 hours later. Between the birth of the piglets, the ear syringe was rinsed with water and the pliers were soaked in alcohol solution. Needle teeth were clipped at birth in piglets born to gilts because of the general nervousness of gilts.

Control litters were not handled until 24 hours after the last piglet was farrowed in each litter.

At one day of age, both control and treated piglets were weighed, their needle teeth and umbilical cord were clipped, tail docked, and ears notched, and scours medication was administered orally and iron dextran intramuscularly.

Attended gilts delivered 10.3 piglets on average, 0.2 stillborn and 10.1 liveborn. Similar values for unattended gilts were 9.2, 0.7, and 8.5; for attended sows, 10.1, 0.2, and 9.9; and for unattended sows, 10.3, 0.6, and 9.7. Birthweight in respective treatment groups averaged 1.3 kilograms, 1.3, 1.5, and 1.3, respectively, while number of piglets weaned per litter averaged 9.4, 7.1, 8.4, and 7.7. The proportion of piglets that survived to weaning at four weeks was greater for attended litters than for unattended (.89 versus .81; P=.01), and piglets from gilts had a higher survival rate than did those from sows (.89 versus .81; P=.01).

Of the piglets that weighed less than 1 kilogram (2.2 pounds) at birth, significantly more survived to weaning in attended litters than in unattended (.84 versus .43 survival rate; P<.0002).

In recapitulation, there were 298 piglets born to unattended dams, 260 to attended dams. Attended dams weaned 88.5% of their piglets, while unattended dams weaned 80.5% of theirs. The stillbirth rate in unattended litters was 6.3%, while it was 1.9% in attended litters. Sixty-five piglets weighing less than 1 kg were born in unattended litters, and 43.1% survived, while 31 were born in attended litters, and 83.9% survived.

From these results we can conclude that attending farrowing apparently reduced stillbirth rate, increased survival of small piglets, and increased the number of piglets weaned per litter. Two practices which would make farrowing attendance more feasible would be an approved drug for clustering breeding days or an approved drug for clustering farrowing times. Either would allow producers to justify continuous attendance at farrowing time.

December, 1982 1982-12
University of Illinois at Urbana-Champaign
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Lysine Supplementation of Sorghum-Sesame Seed Meal Lactation Diets and Productive Response of Gilts and Sows [1]

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Sorghum grain is the second most important cereal fed to swine in the North American continent. Within the United States, in 1977, Illinois ranked 12th in sorghum production with 54% of the grain produced used on the farm of origin (Leath et al., 1981).

Extensive literature is available concerning the use of sorghum in growing swine diets; limited observations, however, have been made for breeding swine. In 1977, Haught et al. suggested the need for lysine supplementation of sorghum-based gestation and lactation diets. The objective of the present report is to evaluate the need for lysine supplementation of sorghum-based lactation diets.

METHODOLOGY

Twenty-eight crossbred first-litter gilts and 28 crossbred sows with an average of 2.4 previous parities were used. The animals were moved to farrowing crates, in environmentally controlled buildings, at day 109 post-coitum. Farrowing crates were provided with partially slotted floors, nipple waterers and a supplemental heat source for the piglets.

Gilts and sows were weighed at gestation day 109, farrowing and weaning (28-day post-parturition) and their progeny were weighed at birth, lactation day 14 and at weaning.

Experimental diets (table 1) were based on the supplementation of sorghum with sesame-seed meal. The inclusion of sesame-seed meal as a protein supplement was considered for two reasons: sesame-seed meal is generally available in areas where sorghum is produced and, as sorghum, is notably deficient in lysine, allowing maximum utilization of crystalline lysine. The level of protein in the diets surpassed the NRC (1979) recommended levels, except for lysine. Diets were: basal (with a level of lysine 40% below that recommended and basal + L-lysine•HCl (made adequate in the amino acid by the addition of .31% L-lysine•HCl to the basal diet). The lysine supplementation was accomplished at the expense of sorghum. The animals were fed the experimental diets ad libitum starting at farrowing and for the entire

[1]The assistance of S. Williamson, D. Alexander and J. Heffernan in animal husbandry and H. Cook in diets mixing is gratefully acknowledged.

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lactation period (28 days).

At lactation day 21 milk production was measured and milk samples were collected for analysis of protein, fat and total solids. Standard farrowing house procedures (iron shots, needle teeth clipping, etc.) were employed.

Table 1. Diets Composition (%)[a]

Ingredients	Basal	Basal + lysine
Sorghum (10)[b]	85.00	84.69
Sesame-seed meal (49)[b]	12.35	12.35
Vitamin premix	.10	.10
Trace mineral premix	.35	.35
Def. rock phosphate	1.94	1.94
Limestone	.26	1.26
L-lysine·HCl (75)[c]	---	.31
Total	100.00	100.00
Analyzed composition, %[d]		
Crude protein (N x 6.25)	14.56	14.75
Lysine	.35	.58
Threonine	.44	.44

[a]As fed.

[b]% crude protein of ingredient.

[c]Available lysine, %.

[d]Average of four triplicate analyses.

RESULTS

Within age groups, the initial weight of the animals was similar. Obviously, sows were heavier ($P<.001$) than gilts as can be observed in table 2. Summarized in table 2 is the productive performance of sows and gilts. Lactation diet consumption was similar within dietary treatment but different ($P<.02$) when sows and gilts were compared, which was expected, given the greater body weight of sows. It should be noted that feed intake in this experiment was below what is normally expected of lactating swine fed ad libitum. We believe that particle size may have been responsible, as some bridging was observed in the feeders.

Table 2. Productive Performance of Sows and Gilts Fed Sorghum-Sesame Seed Meal Lactation Diets

Criterion	Experimental treatment[a]				SEM[b]
	Gilts-lys	Sows-lys	Gilts+lys	Sows+lys	
Gestation day 109, wt. (kg)[c]	145.0	190.0	147.0	186.0	5.855
Lactation diet intake (kg)[d]	107.0	121.0	111.5	118.0	3.853

(Table 2 continued on next page)

Table 2, Continued

Criterion	Experimental treatment[a] Gilts-lys	Sows-lys	Gilts+lys	Sows+lys	SEM[b]
Lactation wt. loss (kg)[e]	20.0	22.0	8.5	10.5	3.524
No. piglets alive at birth[f]	8.6	9.8	7.7	10.5	.710
No. piglets alive at day 14[g]	7.3	7.6	6.7	8.1	.552
No. piglets alive at day 28[g]	7.1	7.4	6.7	7.8	.533
Litter wt. at birth (kg)[h]	37.3	42.7	41.0	43.8	2.900
Piglets ADG birth to day 14 (g)[i]	140	150	170	150	11.801
Piglets ADG day 14 to day 28 (g)[j]	150	170	200	170	13.802

[a]Fourteen observations per treatment; 28-day lactation period.

[b]Standard error of the mean.

[c]Sows were heavier initially (P<.001).

[d]Sows had higher feed intakes (P<.02).

[e]Lysine supplementation prevented greater wt. losses (P<.002).

[f]Sows farrowed more piglets (P<.003).

[g]Sows tended to maintain larger litters throughout lactation (P<.16).

[h]Sows tended to farrow heavier litters (P<.16).

[i]Lysine supplementation interacted with age group (P<.18).

[j]Lysine supplementation interacted with age group (P<.05).

Sow weight change during lactation responded positively to lysine supplementation (P<.002) where the presence of supplemental lysine prevented greater weight losses. This indicates that lysine-deficient gilts and sows had to sacrifice more of their body reserves in order to satisfy the lysine needs for milk production. It is evident that this mechanism was not sufficient to supply needs totally, since piglet average daily gain (ADG) after 14 days tended to be greater (P<.18) when the dam had received lysine supplementation. This tendency was increased by 28 days. Lysine supplementation interacted (P<.05) with age group. Litters from sows did not respond to the lysine supplementation. It could be argued that this is an effect of the number of suckling piglets, but as could be seen in table 2, the number of piglets was very similar, when dietary treatments were compared, although sows tended (P<.16) to wean more piglets, a direct reflection of more piglets farrowed (P<.003).

Table 3 summarizes results obtained for milk production and composition. At the time when milk production was measured, sows had larger litters (P<.03). Therefore, to account for this source of variation milk production is expressed as the yield (in kg) per piglet per day. Sows produced more milk per piglet (P<.01). The effect of lysine supplementation was strong (P<.001), resulting in a significant improvement in milk production. Regardless of age group, milk fat and milk protein were not influenced by treatment or age group. Milk dry matter was higher (P<.08) in milk from gilts.

Table 3. Milk Production and Composition from Sows and Gilts Fed Sorghum-Sesame Seed Meal Lactation Diets

Criterion	Experimental treatment[a]				SEM[b]
	Gilts-lys	Sows-lys	Gilts+lys	Sows+lys	
No. piglets alive at day 21[c]	7.2	7.6	6.7	8.0	.541
Milk yield, $kg \cdot pig^{-1} \cdot d^{-1}$[d]	.520	.730	.740	.860	.0442
Milk protein, %	4.4	4.4	4.6	4.5	.100
Milk fat, %	8.1	7.8	7.9	8.0	.329
Milk dry matter, %[e]	18.2	17.4	17.3	16.9	.392

[a]Fourteen observations per treatment at lactation day 21.

[b]Standard error of the mean.

[c]Sows had larger litters (P<.03).

[d]Sows (P<.01) and lysine supplementation (P<.001) resulted in higher milk yields.

[e]Gilts had higher milk dry matter (P<.08).

The milk production response to lysine supplementation is in agreement with the piglet weight gain and lactation weight loss results. Sow milk production responded to lysine supplementation but this was not reflected in piglet weaning weights. Other variables, such as number of sucking piglets, diarrhea and possibly milk composition play important roles in piglet weight gains. Gilts produced milk with a higher dry matter content than sows. This could be a reflection of the total milk output. Milk fat did not show any relationship to treatments and although an improvement in milk protein yield is to be expected after lysine supplementation (Lewis and Spee, 1973), nothing could be concluded from the small numerical differences observed.

SUMMARY

Lysine supplementation of sorghum-sesame seed meal lactation diets resulted in improvements in performance, preventing excessive weight losses during lactation and allowing greater milk yield. Based on piglets' weight gains during lactation, a beneficial effect of lysine was observed in gilts, but not in sows, suggesting that sows are more able to withstand a lysine deficiency or that sows have lower lysine requirements than gilts during lactation.

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DECEMBER, 1983

SWINE RESEARCH REPORTS

Agricultural Experiment Station
Cooperative Extension Service
College of Agriculture
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Contents

1983-1 Efficacy of Several Soybean Protein Preparations for the Weanling Pig
V. L. O'Hearn-Mennenga and R. A. Easter

1983-2 Effect of a Feed Additive on Feed Intake of Ad Libitum-Fed Sows and of Nursing Piglets
A. H. Jensen, R. A. Gilbert, and T. F. Park, Jr.

1983-3 The Level of Estrone Sulfate in the Plasma of the Pregnant Sow as an Indication of Fetal Number
P. J. Dzuik

1983-4 Lysine Supplementation of Reduced Protein Swine Diets
B. J. Kerr, D. W. Giesting, R. A. Easter, D. H. Baker, F. K. McKeith, and P. J. Bechtel

1983-5 Influence of Meal Frequency and Lysine Supplementation on Nitrogen Retention in Growing Pigs
D. W. Giesting, H. Cook, G. R. Frank, and R. A. Easter

1983-6 Response of Weanling Pigs to Supplementation of Corn-Soybean Meal Diets with Organic Acids and(or) Sodium Bicarbonate
D. W. Giesting and R. A. Easter

1983-7 Riboflavin Requirement of Gestating Swine
G. R. Frank, R. A. Easter, and J. M. Bahr

1983-8 Influence of Pre-Rigor Processing, Mechanical Tenderization, Tumbling Method, and Processing Time on the Quality and Yield of Ham
Robert R. Motycka and Peter J. Bechtel

1983-9 The Effects of Internal Temperature and Thickness on Palatability of Pork Loin Chops
S. L. Simmons, T. R. Cau, and F. K. McKeith

1983-10 Feed Additive Studies with Newly Weaned Pigs: Efficacy of Copper, Antibiotics, and Citric Acid
Michael S. Edmonds, Oscar A. Izquierdo, and David H. Baker

1983-11 Responses of Pigs in Crowded Environments to Dietary Antimicrobials
A. H. Jensen, T. F. Park, and J. D. Tracy

1983-12 High-Oil Corn and Antimicrobials in Diets for Growing Pigs
A. H. Jensen and T. F. Park

6

1983-13 Utilization of Dehulled Sunflower Seeds by Growing Pigs
C. C. Lin and A. H. Jensen

1983-14 Farrowing Management with Prostaglandin
P. A. Eichen, B. F. Brohammer, and L. H. Thompson

1983-15 Energetics of Growth in Pigs
R. W. Jones and R. A. Easter

1983-16 Behavior of the Mated Gilt in a Turn-Around Gestation Crate
J. W. McFarlane and S. E. Curtis

1983-17 Toy Preferences in Young Pigs
T. Grandin and S. E. Curtis

1983-18 Objective Measurement of Effects of Environmental Complexity on Young Pigs
T. Grandin, S. E. Curtis, and W. T. Greenough

Urbana, Illinois December, 1983

Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, in cooperation with the U. S. Department of Agriculture. WILLIAM R. OSCHWALD, Director, Cooperative Extension Service, University of Illinois at Urbana-Champaign. The Illinois Cooperative Extension Service provides equal opportunities in programs and employment.

December, 1983
1983-1

University of Illinois at Urbana-Champaign
College of Agriculture
Cooperative Extension Service
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Efficacy of Several Soybean Protein Preparations for the Weanling Pig[1]

V. L. O'HEARN-MENNENGA AND R. A. EASTER

There are a variety of methods available for processing soybeans to produce protein products for the food and animal feeding industries. Clear differences exist in protein concentration, degree of oil extraction and composition of the residual carbohydrate fraction. It is reasonable to expect that there may also be differences in nutritional value, particularly when these products are used in the diet of the nutritionally sensitive three-week-old pig.

Relatively little research has been conducted to evaluate different forms of soy protein for the pig at weaning. Decuypere et al. (1981a) has shown that a partly hydrolyzed soluble soybean protein isolate enhanced *in vivo* gastric proteolysis in comparison to a water-insoluble soybean protein isolate when fed to five-week-old pigs. These results were consistent with early findings (Decuypere et al., 1981b) that nitrogen digestibility in pigs fed artificial diets at 12 days of age was greatest when the diet contained soy protein that was totally soluble in water or a soy protein that was easily dispersed in water. It has been suggested (Sève et al., 1975) that the portion of soluble to insoluble protein in the diet may be important to both digestive function and performance of the piglet. Mateo and Veum (1980) reported reduced performance of 1-to 29-day-old pigs when fed an isolated soy protein diet in comparison to a casein-based diet. These workers, however, did not define the physiochemical properties of the soy protein that was utilized. Thus, the utility of concentrated soy proteins for the weanling-age pig remains an open question.

It is reasonable that the fat contained in whole soybeans may be of some nutritional value and Noland et al. (1976) offers data to support this notion. These workers reported that soybean flakes cooked for either 12 or 24 minutes at 704 g pressure per cm^2 resulted in superior performance of three-week-old pigs when compared to conventional soybean meal as a protein source. Additional data to support this method for processing whole soybeans is not available.

The general lack of definitive information suggests that a well-defined evaluation of various soybean proteins is justified.

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[1]Research funded by a grant from A. E. Staley Manufacturing Company.

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EXPERIMENTAL PROCEDURE

Pigs from similar genetic backgrounds were weaned at an average of 21 ± 2 days of age and assigned to treatments from homogenous outcome groups based on ancestry, weight and sex. There were eight experimental treatments with five pen-replicate treatment. Each pen-replicate consisted of five pigs. Replicates were formed in blocks with blocking based on weaning; i.e., when a sufficient number of pigs were at 21 ± 2 days of age to start a block of eight pens (40 pigs), those pigs were weaned and the block started on test; the subsequent block was started on test when the next group of 40 pigs reached 21 ± 2 days of age.

Experimental diets (Table 1) were formulated to be isocaloric (1545 kcal of ME/lb) and isonitrogenous (22% crude protein) with a minimum lysine content of 1.10%. Energy levels were maintained at a constant value by the addition of tallow. The experimental diets are described below:

Diet 1. Corn + conventionally processed (48% CP) dehulled soybean meal.
2. Corn + dried skim milk.
3. Corn + soy protein concentrate (PROCON® by the A. E. Staley Co.).
4. Corn + texturized soy protein concentrate (Texturized PROCON®, by A. E. Staley Co.).
5. Corn + a blend of heat-processed extruded soybeans + soy protein concentrate (HI-PRO®, Triple F Feeds).
6. Corn + 50% crude protein soy flour (bland) (Bland-50, A. E. Staley Co.).
7. Corn + 50% crude protein soy flour, heat-treated (Bland-50, A. E. Staley, Co.).
8. Corn + water-extracted soy protein concentrate (PROMAX®-70, Griffith Foods).

The experimental diets were mixed in 1000-pound batches and then pelleted in a California® pellet mill equipped with a 3/16-inch die.

Pigs were housed in elevated deck nursery pens with solid partitions, nipple watering devices and expanded metal floors. Feed was offered ad libitum through galvanized steel self-feeders. The room temperature was maintained at 86 to 89.6°F during the first week of the experiment, and then gradually reduced to 73.4°F by the end of the experimental period.

Pigs were observed daily for evidence of stool looseness during the first 14 days after assignment to treatment. The subjective scoring system shown below was used.

1 = soft but formed stools
2 = soft with some texture; not formed
3 = very soft, little texture or form
4 = watery, no texture or form

Each pig was assigned a fecal score which was then summed for the pen to obtain a total pen score indicative of degree of looseness.

Weight gain data and feed consumption data were obtained at the end of the first, second and fifth weeks of the experiment. Weight data was recorded for individual pigs; feed consumption data was recorded on a "per pen" basis. The experiment was terminated at the end of five weeks when the pigs were approximately eight weeks of age.

Table 1. Composition of Experimental Diets, %[a]

Ingredient	Diet Number 1	2	3	4	5	6	7	8
Corn	51.46	34.53	61.15	59.61	57.42	55.32	55.01	60.91
Soybean meal (48%)	33.28	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Skim milk	-0-	52.52	-0-	-0-	-0-	-0-	-0-	-0-
PROCON®	-0-	-0-	22.31	-0-	-0-	-0-	-0-	-0-
Texturized PROCON®	-0-	-0-	-0-	23.89	-0-	-0-	-0-	-0-
HI-PRO LTI soy flour	-0-	-0-	-0-	-0-	29.84	-0-	-0-	-0-
Bland-50 (flour)	-0-	-0-	-0-	-0-	-0-	29.30	-0-	-0-
Bland-50 (heat trt'd)	-0-	-0-	-0-	-0-	-0-	-0-	29.59	-0-
PROMAX®-70	-0-	-0-	-0-	-0-	-0-	-0-	-0-	22.65
Whey	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Tallow	2.72	2.14	4.00	3.98	-0-	2.80	2.83	3.84
Limestone	.77	.06	.87	.90	.47	.74	.73	.44
Def. rock phos.	.97	-0-	.87	.82	1.47	1.04	1.04	1.36
Trace min. salt[b]	.35	.35	.35	.35	.35	.35	.35	.35
Vitamin mix[c]	.20	.20	.20	.20	.20	.20	.20	.20
ASP-250	.25	.25	.25	.25	.25	.25	.25	.25
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis								
Crude protein, %	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
Total fat, %	5.09	4.00	6.62	6.38	5.88	5.28	5.22	6.34
Lysine, %	1.28	1.44	1.10	1.17	1.13	1.16	1.17	1.22
ME, kcal/lb	1545	1545	1545	1545	1544	1544.5	1545	1547

[a]All diets were formulated to contain a minimum of .80% calcium and .60% phosphorus.

[b]Contains the following in percent: Selenium, .00286; iodine, .01; copper, .229; manganese, .57; iron, 2.57; zinc, 2.86; cobalt, .02 and sodium chloride, 78.0.

[c]Contains the following per lb of mix: vitamin A, 1,500,000 IU; vitamin D_3; 150,000 IU; vitamin E, 10,000 IU; riboflavin, 500 mg; d-pantothenic acid, 2.750 mg; niacin, 7,500 mg; choline chloride, 75,000 mg; vitamin B_{12}, 8 mg.

The data were summarized and statistically analyzed as a randomized complete block design. Analysis of data was accomplished using the Statistical Analysis System[2]. Treatment means were compared by the LSD (least significant difference) method following the determination that there was a significant (P<.05) treatment effect.

RESULTS AND DISCUSSION

This trial was started on June 18, 1982 and terminated on July 30, 1982. A total of 200 pigs with an average initial weight of 12.85 lb were used in this experiment. Average initial weights, average two-week weights and average final weights are in Table 2. One pig on Diet 4 died after two weeks on trial (no autopsy was performed), and one pig on Diet 6 was taken off test due to a bad leg.

[2]Statistical Analysis System, The SAS Institute Inc,, Raleigh, North Carolina.

Table 2. Average Initial Weights (INI), Average Two-week (TWO) Weights and Average Final Weights (FIN) of Pigs on Test[a]

Protein Source	INI, lb	TWO, lb	FIN, lb
Soybean meal	13.71	19.21	42.64
Dried skim milk	12.56	22.95	47.51
PROCON®	12.23	18.37	39.25
PROCON® flakes	12.98	18.61	38.68
HI-PRO®	12.47	19.69	43.10
Bland-50	12.98	17.47	36.08
Heat-treated Bland-50	12.98	18.94	39.38
PROMAX® -70	12.85	20.26	43.19

[a]Weights are an average of five replicate pens.

Performance of pigs after two weeks on trial is shown in Table 3. Pigs consuming the
daily_gain (ADG) of .70 lb and a gain:feed of .96. All pigs consuming the different soy protein diets had improved gains over those pigs consuming the standard soybean meal diet, except for those consuming the Bland-50 diet. However,the only significant (P<.05) improvement observed was with pigs consuming the HI-PRO® and PROMAX®-70 diets, with those two groups of pigs having equal gains and feed efficiencies.

With the exceptions of the milk diet of which those pigs had the highest consumption and the Bland-50 diet pigs which had the lowest consumption, there was not much difference in feed intake. Pigs consuming the Bland-50 diet had a significantly (P<.05) lower intake than any other group of pigs, possibly indicating that the pigs did not like the taste of the diet.

Table 3. Performance of Pigs After Two Weeks on Test[a]

	Criterion		
Protein Source	ADG, lb	ADF, lb	G/F
Soybean meal	.37[d]	.64[bc]	.58[e]
Dried skim milk	.70[b]	.73[b]	.96[b]
PROCON®	.42[d]	.68[bc]	.62[de]
PROCON® flakes	.37[d]	.59[c]	.63[de]
HI-PRO®	.48[c]	.70[b]	.69[cd]
Bland-50	.31[e]	.48[d]	.65[de]
Heat-treated Bland 50	.40[d]	.66[bc]	.61[de]
PROMAX®-70	.51[c]	.66[bc]	.77[c]

[a]Values are means of five replicate pens.

[b,c,d,e]Means in a column with different superscripts are different (P<.05).

Pigs consuming the PROMAX®-70 Diet had the second-best feed efficiency as compared to those pigs consuming the skim milk diet. While the improvement in feed efficiency was not different from pigs consuming the HI-PRO® diet, it was improved (P<.05) over those pigs consuming the other soy protein.

Pigs consuming the standard soybean meal diet had the poorest feed efficiencies for the first two weeks on trial, suggesting that the small pig (less than 22 lb) cannot as easily digest soybean meal as it can the other soy proteins. However, only with those pigs consuming the dried skim milk, PROMAX®-70 and HI-PRO® diets was the improvement in feed efficiency significant (P<.05).

Pig performance during the last three weeks of the trial is shown in Table 4. Again those pigs consuming the dried skim milk diet had the best performance (P<.05) with gains of 1.21 lb and a gain:feed ratio of .69. Those pigs consuming soybean meal, HI-PRO® and PROMAX®-70 had gains equivalent to pigs fed dried skim and slightly lower (P<.05) gain:feed ratios. Pigs consuming the four other soy proteins had similar rates of gain but were lower (P<.05) than the above-mentioned protein sources.

Pigs consuming the PROMAX®-70 diet had the lowest level of feed intake (P<.05), but also had a high gain:feed ratio indicating a much improved digestibility over the first two weeks on trial.

Trends in gain:feed ratios were similar to those of rate of gain, with pigs consuming dried skim milk have the best gain:feed ratio. Pigs fed soybean meal, HI-PRO®, PROMAX®-70, and PROCON® had similar gain:feed ratios which were lower (P<.05) than pigs fed the dried skim milk diet, and those pigs fed the PROCON® flakes, Bland-50 and Heat-treated Bland-50 had the lowest (P<.05) gain:feed ratios.

Table 4. Last Three Weeks On Trial[a]

Protein Source	ADG, lb	ADF, lb	G/F
Soybean meal	1.17^{b}	1.78^{b}	$.66^{cd}$
Dried skim milk	1.21^{b}	1.76^{bc}	$.69^{b}$
PROCON®	1.03^{c}	1.67^{c}	$.62^{de}$
PROCON® flakes	1.01^{cd}	1.69^{c}	$.60^{f}$
HI-PRO®	1.17^{b}	1.80^{b}	$.65^{cde}$
Bland-50	$.95^{d}$	1.54^{d}	$.62^{e}$
Heat treated Bland-50	1.01^{cd}	1.67^{c}	$.60^{f}$
PROMAX®-70	1.14^{b}	1.74^{e}	$.66^{bc}$

[a]Values are means of five replicate pens.

[b,c,d,e,f]Means in a column with different superscripts are different (P<.05).

Pig performance, overall, is shown in Table 5. The best overall performance was that of those pigs on the milk diet. Average daily gains and feed efficiencies of those pigs were superior to all other pigs consuming the different soy protein diets (P<.05). Pigs consuming the HI-PRO® and PROMAX®-70 diets had comparable gains and feed efficiencies. While the gains of these pigs were not statistically different from the gains of pigs consuming the standard soybean meal control, the feed efficiencies of pigs consuming the HI-PRO® and PROMAX®-70 diets was improved over that of the pigs consuming the standard soybean meal control (P<.05).

Pigs consuming the remaining four soy protein diets (PROCON®, PROCON® flakes, Bland-50 flour, and heat-treated Bland-50 flour) had gains which were numerically smaller than pigs on the standard soybean meal diet, but only with those pigs consuming the Bland-50 flour was the difference significant ($P<.05$). The feed efficiencies of the pigs on these four diets again were numerically lower but not statistically different from the pigs on the standard soybean meal.

Table 5. Performance Data, Overall[a]

Protein Source	Criterion: ADG, lb	ADF, lb	G/F
Soybean meal	.84[cd]	1.30[bc]	.65[de]
Dried skim milk	.99[b]	1.32[bc]	.75[b]
PROCON®	.77[d]	1.25[bc]	.62[e]
PROCON® flakes	.75[de]	1.21[c]	.62[e]
HI-PRO®	.88[c]	1.34[b]	.66[cd]
Bland-50	.66[e]	1.08[d]	.61[e]
Heat-treated Bland-50	.75[d]	1.23[bc]	.61[e]
PROMAX®-70	.86[c]	1.28[bc]	.67[c]

[a]Values are means of five replicate pens.

[b,c,d,e]Means in a column with different superscripts are different ($P<.05$).

There were only small differences in intake, with pigs consuming the Bland-50 flour having the poorest intake. Except for one pen of pigs on that diet all pigs on trial performed exceptionally well. There was a problem during the first two weeks of the trial with pellets breaking up in the feeders when chewed and mouthed by the young pigs. Until the pigs were older it was necessary to rake down and clean out the feeders several times daily. However, this problem was not evident with the milk diet; those pellets appeared to be harder and did not break up easily in the feeder.

Pigs were observed daily for looseness and scours. Some scouring was apparent the first two weeks of the trial, but there were no discernible differences which could be attributed to any particular treatment.

Results of this trial indicate that a 22% crude protein diet with a minimum lysine level of 1.1% is adequate for three-week-old weaned pigs. Performance of pigs on the dried skim milk diet was superior to all others. Pigs consuming the HI-PRO® and PROMAX®-70 diets had performance equal to that of pigs on the standard soybean meal diet. Pigs consuming the remaining four soy protein diets (PROCON®, PROCON® flakes, Bland-50 and heat-treated Bland-50) had slightly depressed performance as compared to the standard soybean meal pigs. Pigs consuming the Bland-50 diet had the poorest performance overall. As intake was depressed over that of the heat-treated Bland-50, it is possible that the pigs did not like the taste of the diet.

The improvement in performance of pigs consuming the standard soybean meal diet after the first two weeks on trial suggests that as the pig gets older it can more easily digest the soybean meal present in the diet.

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Effect of a Feed Additive on Feed Intake of Ad Libitum-Fed Sows and of Nursing Piglets

A. H. JENSEN, R. A. GILBERT AND T. F. PARK, JR.

Many producers indicate that their lactating sows do not consume enough feed to meet the needs for maximum milk production and maintenance of a good physiological state. Factors such as restricted capacity because of limited feeding during gestation or environmental stress, especially high ambient temperatures, have been suggested as possible causes.

A naturally occurring plant steroid, sarsaponin, extracted from the Yucca plant, has shown growth-promoting effect when included in diets of growing-finishing pigs (Foster, 1983). This gain advantage seemed to be associated with a slightly increased feed intake. Thus, if this product (commercially formulated product, MICRO-AID) stimulated feed intake, it could be beneficial in diets for lactating animals, and perhaps stimulate creep feed intake of nursing piglets. Thus, an experiment was conducted to evaluate MICRO-AID on (1) feed intake of ad libitum-fed lactating sows and (2) on creep feed consumption by nursing piglets between 14 and 28 days of age.

EXPERIMENTAL PROCEDURES

Forty-five sows from four farrowing groups (farrowing in December, 1982, January, February and March, 1983) were used. All sows received a corn-soybean meal diet during gestation. At day 3 post farrow, assignment to lactation dietary treatment was made randomly from pairs of sows, pairing based on sow parity and weight, and number and condition of piglets in the litter. Creep diets were assigned randomly to litter-pairs within Control and MICRO-AID sow groups and were available from about 14 to 28 days post farrow.

Composition of the sow lactation and the creep diets are shown in table 1. The lactation diet was fed twice daily to minimize wastage and to enhance behavior observation. Individual sows were given as much as would be consumed between feedings, thus approximating ad libitum feedings. When a litter was two weeks of age creep feed was made available, using a small, 2-hole feeder.

Room temperature in the partially-slotted floor farrowing units was maintained at about 70^{o}F with a thermostatically controlled gas space heater. A 250-watt lamp provided supplemental heat in the piglet sleeping area.

A. H. Jensen is a Professor of Animal Science, R. A. Gilbert is a Foreman Herder, and T. F. Park, Jr. is an Associate Animal Scientist in the Department of Animal Science, University of Illinois, Urbana, Illinois 61801.

RESULTS

Sow body weight change, daily feed consumption, litter size and litter weight were not significantly affected by diet during the lactation period of day 4 to day 28 postpartum (table 2). Although there was considerable variation in daily feed intake among replicates, the average intake was at a very acceptable level and similar within replicates between those sows getting Diet I and those getting Diet II (MICRO-AID).

Creep feed consumption for piglets having access to Diet IV (MICRO-AID) was greater than for the piglets with access to Diet III (control creep). Due to the great variation among replicates, this difference (1.77 vs 1.32) was not statistically significant. However, in six of the eight comparisons the higher values for creep feed intake were for the piglets having access to Diet IV (MICRO-AID). Piglets nursing sows fed Diet I consumed, on the average, less creep feed than those nursing sows having Diet II. There was no interaction between sow and piglet treatments.

SUMMARY

1. The addition of a sarsaponin (four pounds of MICRO-AID per ton of diet) did not significantly affect feed intake of lactating sows. Average daily intake for all sows (21 fed the control diet, 24 fed the control plus MICRO-AID) was 17.8 pounds from day 4 to day 28 post farrow. Litter size and weight at weaning were not affected by sow diet.

2. Average creep feed consumed per piglet from day 14 to day 28 was nonsignificantly higher with the MICRO-AID diet (1.77 pounds per piglet) than with the control creep diet (1.32 pounds per piglet).

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Table 1. Composition of Diets

Diet Diet number	Lactation I	 II	Creep III	 IV
Ground yellow corn (8.8% C.P.)	84.05	83.85	48.20	48.00
Soybean meal (48.5% C.P.)	13.00	13.00	26.00	26.00
Rolled oats (14% C.P.)	---	---	20.00	20.00
Dried whey (12% C.P.)	---	---	2.50	2.50
Dicalcium phosphate	1.25	1.25	1.75	1.75
Ground limestone	1.25	1.25	1.00	1.00
Trace mineralized salt[a]	0.35	0.35	0.35	0.35
Vitamin mix[b]	0.10	0.10	0.20	0.20
MICRO-AID[c]	---	0.20	---	0.20
	100.00	100.00	100.00	100.00
Calculated, %				
Crude protein	14.00	14.00	20.00	20.00
Lysine	.60	.60	1.00	1.00
Calcium	.75	.75	.80	.80
Phosphorus	.50	.50	.60	.60

[a]Contained, %: NaCl, 93.74; iron, 2.57; copper, .229; cobalt, .0214; manganese, .571; zinc, 2.86; iodine, .01; selenium, .00286.

[b]Contained per kg: 3,000,000 IU vitamin A; 300,000 IU vitamin D_3; 11,000 IU vitamin E; 2 grams vitamin K; 2 grams riboflavin; 15 grams niacin; 10 grams calcium pantothenate; 200 grams choline chloride, 22 milligrams vitamin B_{12}.

[c]MICRO-AID provided by Distributors Processing, Inc., Noblesville, Indiana 46060.

Table 2. Summary of Sow Lactation Feed Intake and Weight Change

Replicate[a]	Number of litters	Avg. sow wt., lbs[b] Start[a]	Finish	Avg. wt. chg., lbs	Avg. daily feed, lbs[a]
Control Diet (I)					
1	4	537	576	+39	25.1
2	4	464	451	-13	17.6
3	7	504	508	- 4	17.2
4	6	475	449	-26	13.4
Average	(21)	494	493	- 1	17.7
MICRO-AID Diet (II)					
1	4	484	471	-13	22.9
2	5	464	469	+ 5	17.6
3	8	469	462	- 7	19.6
4	7	449	431	-18	13.2
Average	(24)	465	456	- 9	17.9

[a]Replicates 1 through 4 represent monthly farrowings in December, January, February and March, 1982-1983.

[b]Average from day 4 to day 28 post farrow.

Table 3. Summary of Litter Size and Performance

Replicate[a]	Number of litters	Litter at birth: Avg. no. of piglets Total	Live	Avg. pig wt., lbs	Litter at weaning: No. of piglets	Avg. wt., lbs[b]
Control Ration (I)						
1	4	10.7	9.2	3.65	8.5	19.1
2	4	11.7	10.2	3.30	9.5	12.8
3	7	10.5	9.6	3.37	8.2	12.3
4	6	11.8	11.2	3.01	9.5	14.1
Average	(21)	11.1	10.1	3.31	8.9	14.2
MICRO-AID Ration (II)						
1	4	12.7	11.0	3.56	9.7	20.0
2	5	9.6	8.0	3.67	8.0	14.1
3	8	11.7	10.0	3.30	9.3	11.2
4	7	11.0	10.6	3.21	9.8	14.1
Average	(24)	11.1	9.9	3.39	9.2	14.1

[a]Replicates 1 through 4 represent monthly farrowings in December, January, February and March, 1982-83.

[b]Pigs weaned at 28 days of age.

Table 4. Summary of Creep Feed Consumption by Nursing Piglets from Day 14 to Day 28 of Age

MICRO-AID	Creep feed consumed, lbs –	Creep feed consumed, lbs +	
Control Diet Sows			Total
Replicate 1[a]	2.35(17)[b]	3.19(17)	
Replicate 2	1.21(19)	1.25(19)	
Replicate 3	0.51(21)	2.11(37)	
Replicate 4	0.79(30)	0.86(27)	
Average	1.12(87)	1.79(100)	1.48(187)
MICRO-AID Diet Sows			
Replicate 1	3.61(22)	3.12(17)	
Replicate 2	0.59(18)	1.58(22)	
Replicate 3	1.76(29)	2.71(44)	
Replicate 4	0.29(31)	0.11(38)	
Average	1.50(100)	1.75(121)	1.64(221)
Total average	1.32(187)	1.77(221)	

[a]Replicates 1 through 4 represent monthly farrowing in December, January, February and March, 1982-83.

[b]Values in parentheses represent number of piglets.

December, 1983 1983-3

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The Level of Estrone Sulfate in the Plasma of the Pregnant Sow as an Indication of Fetal Number

P. J. DZUIK

When a sow or gilt becomes pregnant several hormone levels change. Some of the hormones are produced by the sow. Progesterone is the primary hormone associated with pregnancy. It is produced by the copora lutea on the ovaries of the sow and is essential for maintenance of pregnancy. It allows the uterus to grow, it prevents the uterus from contracting and keeps the sow out of heat. The embryos and fetuses also produce a number of hormones. One of the first hormones that the pig embryo produces is estrone. Estrone is one of the estrogens. It causes uterine growth, increases the blood supply to the uterus and helps maintain the functioning of the copora lutea to produce progesterone. The embryos first produce detectable amounts of estrone at about day 16 of gestation. Each embryo produces a certain amount thus the greater the number of embryos the higher the level of estrone. The amount produced by each embryo increases to day 30 of gestation then declines sharply. Estrone from the embryo goes to the placenta and is converted to estrone sulfate by the sow's uterus. The form of estrone found in the blood plasma of the sow is then estrone sulfate. Measuring the level of estrone sulfate in the plasma of the sow at day 24 after mating can be useful in two ways. First, pregnant sows have much higher levels than nonpregnant sows thus it is a highly accurate indication of pregnancy. Second, the greater the number of fetuses the higher the level, hence, it also gives an indication of the litter size at day 24. Because the level of estrone sulfate declines at day 30 and remains low until about day 80, knowing the level during that period is not particularly helpful. When part of a litter dies in the uterus and is resorbed after day 40 the level of estrus sulfate in the sow's plasma changes very little. Thus a determination of the level is also not useful in determining the possible effect of a disease or toxin. When the loss of part of the litter occurs before day 30 the level of estrone sulfate is affected and a decision to select against a sow carrying a litter of less than seven fetuses could be made before gestation had progressed beyond day 30. The level of estrone sulfate in the sow can give a quite certain sign of pregnancy between day 20 and day 30 and also gives an indication of the littter size at that time. The level is not helpful for either detection of pregnancy or indication of litter size after day 30.

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December, 1983 1983-4

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Lysine Supplementation of Reduced Protein Swine Diets

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INTRODUCTION

It has been shown (Easter & Baker, 1980; Lunchick et al., 1978; Catron et al., 1953) that with proper lysine supplementation the crude protein level of a corn-soybean meal diet can be reduced by two percentage units without adversely affecting the performance of growing/finishing pigs. Work done by Russell et al. (1983), Gomez-Rojas et al. (1982) and Corley (1980) clearly indicates that essential amino acids other than lysine are deficient in a corn-soybean meal diet formulated at four percentage units below the current NRC (1979) recommendation for crude protein. The adequacy of a lysine-fortified diet formulated to a protein level 2.5 percentage units below the recommended concentration has not been evaluated. The present experiment compared the performance of pigs fed diets to either the NRC recommended level or to a level of either 2.0 or 2.5 percentage units below this recommended level with or without lysine supplementation.

MATERIALS AND METHODS

The experiment involved the use of 240 Landrace-sired pigs housed in environmentally regulated buildings. The five dietary treatments used were based on the variation of crude protein in the diet and the amount of crystalline lysine added. Pigs were fed a grower diet (38 to 110 lbs), early finisher diet (110 to 169 lbs), and late finisher diet (169 to 214 lbs). Diets (table 1) were formulated using crude protein and lysine composition values obtained by chemical analysis of the corn and soybean meal ingredients.

Sequence 1 was formulated to the level of crude protein as recommended by the NRC, sequences 2 and 4 were the 2.0 and 2.5 percentage unit reduced crude protein diets, respectively, and sequences 3 and 5 were 2.0 and 2.5% CP reduced diets with lysine added to meet the recommended level of dietary lysine for the specific phase of growth.

Ten barrows from each treatment were killed at an average liveweight of 231 lbs so that measurements could be made to determine the effect of dietary treatment on carcass characteristics.

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Table 1. Crude Protein and Lysine Levels of Diets

Dietary sequence	Grower CP, %	Grower Lys, %	Early finisher CP, %	Early finisher Lys, %	Late finisher CP, %	Late finisher Lys, %
1	16.0	.78	14.0	.64	13.0	.57
2	14.0	.64	12.0	.50	11.0	.43
3	14.0	.70	12.0	.61	11.0	.57
4	13.5	.61	11.5	.46	10.5	.39
5	13.5	.70	11.5	.61	10.5	.57

RESULTS AND DISCUSSION

Overall performance data are presented in table 2. As protein concentration in the diet was reduced by two percentage units from the positive control sequence, there was a reduction (P<.05) in the rate of gain but not feed intake or feed efficiency. This was unexpected as work done by Brown et al. (1973) shows that more lysine is required to maximize feed efficiency than rate of gain.

Addition of lysine in dietary sequence 3 resulted in growth that was better (P<.05) than the same diet without supplemental lysine (sequence 2) and was not different (P>.10) from the positive control. There was no difference (P>.10) in either feed intake or feed efficiency between sequence 3 and sequence 1.

The reduction of crude protein by 2.5 percentage units, sequence 4, resulted in a depressed gain when compared to either the positive control or to the diet with a 2.0 percentage unit reduction in crude protein, sequence 3. Addition of lysine to this diet, sequence 5, increased gain over sequence 4, but failed (P<.05) to restore gain to a level achieved with the positive control or sequence 3. Feed intake by the pigs receiving sequences 4 and 5 were less than those of either sequence 1, 2 or 3, but the concomitant reduction in gain resulted in similar feed efficiency values.

Table 2. Overall Performance of Grower and Finisher Pigs Fed Different Levels of Crude Protein With or Without Supplemental Lysine

Treatment	1 Pos. (+) cont.	2 + Cont. -2% CP	3 As 2 + Lys	4 + Cont. -2.5% CP	5 As 4 + Lys	Std. error
Daily gain, lbs	1.65	1.59	1.68	1.50	1.59	.011
Daily feed, lbs	5.27	5.18	5.14	4.96	4.85	.038
Gain/feed	.68	.68	.71	.66	.73	.004

Carcass data are presented in table 3. Loin eye area was reduced when pigs were fed diets formulated at a crude protein level of either 2.0 or 2.5 percentage units below the levels recommended by the NRC. Addition of lysine corrected these depressions although there was a strong tendency for dietary sequence 5 to continue to have a reduced loin eye area. Muscle percent followed the changes in loin eye area. Pigs fed the reduced protein diets tended to have more backfat and tenth rib fat compared to the positive control. Lysine additions tended to correct the effect of reduced protein.

Table 3. Effect of Dietary Protein and Lysine Levels on Carcass Criteria

Treatment	1 Pos. (+) cont.	2 + Cont. -2% CP	3 As 2 + Lys	4 + Cont. -2.5% CP	5 As 4 + Lys.	Std. error
Backfat, in.	1.38	1.54	1.47	1.50	1.42	.022
10th rib fat, in.	1.34	1.50	1.42	1.47	1.34	.027
LEA, in.^{2}	4.70	4.39	4.59	4.19	4.40	.057
Muscle, %	50.9	49.1	50.1	48.6	50.0	.231

The results indicate that the reduced protein diets without supplemental lysine do not support maximal gain, feed intake, or lean tissue accretion. They do reaffirm the validity of reducing protein levels by 2.0 percentage units in a corn-soybean meal diet provided that supplemental lysine is used. It does not appear that a 2.5 percentage unit reduction is justified. This may be due to a second limiting amino acid since the lysine levels in sequences 3 and 5 were identical, yet inferior performance was obtained with dietary sequence 5.

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The Influence of Meal Frequency and Lysine Supplementation on Nitrogen Retention in Growing Pigs

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INTRODUCTION

It has been shown by workers at this station (Baker et al., 1975; Easter and Baker, 1980) and others (Catron et al., 1953; Lunchick et al., 1978) that growing/finishing pigs fed free-choice will perform similarly when fed a standard corn-soybean meal diet or a corn-soybean meal diet formulated to a crude protein level two percentage units below NRC (1979) recommendations provided crystalline lysine is added to the low-protein diet.

Recent evidence (Batterham, 1974) suggests that meal frequency may affect the efficiency with which the crystalline lysine is utilized. The amino acids found in intact dietary proteins must first be released from the protein by digestive enzymes before absorption can occur. Crystalline lysine, on the other hand, is already in the free form and could be absorbed immediately. Thus, it is possible that when pigs are meal-fed, the crystalline lysine may reach the cellular sites of protein synthesis well before the other essential amino acids. Because the crystalline lysine, at that instant, would be in excess of cellular needs, it would likely be broken down and used for energy. This is not a matter of concern when pigs are allowed to eat more or less continuously at self-feeders as a "steady state" condition, balancing digestion, absorption and utilization, would exist. However, in those cases where growing/finishing pigs are meal-fed or in the case of the gestating sows fed once daily, there may be a significant impairment of lysine utilization.

We are currently conducting a series of experiments to evaluate this question. The two initial experiments are described herein.

EXPERIMENTAL PROCEDURE

Two nitrogen balance trials involving a total of 44 pigs, initial weights of about 35 pounds, have been conducted. Nitrogen balance trials were used to test the hypothesis that meal frequency affects lysine utilization because unused amino acids are degraded by the liver to energy-yielding compounds and nitrogen which is excreted primarily in the urine. Thus, urinary nitrogen excretion would be expected to give a good indication of the efficiency with which dietary amino acids are utilized.

A 2 x 2 factorial arrangement of treatments was utilized in each experiment. The factors were meal frequency (one meal per day or a similar quantity

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of feed given in three equally spaced meals per day) and diets with or without crystalline lysine.

In Trial I, there were six pigs assigned to each of the four treatments. The treatments were once or three times per day feeding and a 16% crude protein corn-soybean meal diet or a 14% crude protein diet supplemented with crystalline lysine to the lysine level of the 16% crude protein diet. In Trial II, 20 pigs were used, e.g., four treatments and five individual pigs per treatment. Treatments were based on meal frequency, once or three times per day, and lysine supplementation. The diets for Trial I are shown in Table 1 and the diets used in Trial II are shown in Table 2.

Table 1. Diet Composition (Trial I), %

Ingredient	16% CP[a]	14% CP + Lys[b]
Corn	77.90	82.81
Soybean meal (49% CP)	19.40	14.30
Defluorinated rock phosphate	1.25	1.25
Ground limestone	.75	.75
Trace mineralized salt	.35	.35
Vitamin premix	.10	.10
L-lysine·HCl (98%)	-	.19
Antibiotic (ASP-250)	.25	.25

[a]Calculated to contain .81% lysine.

[b]Calculated to contain .66% lysine plus .15% crystalline lysine.

Table 2. Diet Composition (Trial II), %

Ingredient	18% C-Soy[a]	18% C-Sesame[b]
Corn	72.65	68.54
Soybean meal (49% CP)	24.45	29.00
Defluorinated rock phosphate	1.45	1.25
Ground limestone	.75	-
Trace mineralized salt	.35	.35
Vitamin premix	.10	.10
L-lysine·HCl (98%)	-	.51
Antibiotic (ASP-250)	.25	.25

[a]Calculated to contain .96% lysine.

[b]Calculated to contain .56% lysine plus 40% crystalline lysine.

A five day total urine and fecal collection was carried out. During the collection period, pigs within a single replicate were fed to the level of intake of the pig consuming the least amount of feed in that replicate, as determined during a two-week adjustment period. Feces, urine and feed were analyzed for nitrogen content using the macro-Kjeldahl procedures. Differences in nitrogen intake, fecal nitrogen, urinary nitrogen, nitrogen retention (N intake-fecal N-urine N), and nitrogen retention as a percentage of nitrogen intake (N retained ÷ N intake x 100) were calculated.

RESULTS AND DISCUSSION

Trial I

Mean values obtained for this trial are shown in Table 3. An increase in urinary nitrogen excretion (and a decrease in nitrogen retention) was seen when pigs were fed the lysine-supplemented diet in comparison to those fed the 16% corn-soy diet. Nitrogen retention tended to be better for pigs fed three times per day versus those fed once per day on the reduced protein diet. It is believed that amino acids are removed from the blood when levels exceed a certain threshold. More frequent, small meals would tend to limit the increase of free amino acids in the blood to smaller peak levels; thus, less urinary nitrogen excretion should be seen.

Table 3. Results of Trial I[a]

Diet	16% CP		14% CP + Lys	
Meal Frequency	1	3	1	3
Feed intake (lb/d)	1.53	1.54	1.48	1.54
Nitrogen intake (g/d)[b]	17.72	17.91	15.07	15.68
Fecal nitrogen (g/d)[d]	2.54	2.75	2.46	2.69
Urinary nitrogen (g/d)[bc]	5.27	5.46	4.16	3.68
Nitrogen retention (g/d)[ce]	9.91	9.70	8.47	9.31
Nitrogen retention as % of nitrogen intake[fg]	56.0	54.0	55.9	59.5

[a]Each value represents the mean of six pigs.

[b]Effect of diet (P<.001).

[c]Diet x meal frequency interaction (P<.10).

[d]Effect of meal frequency (P<.10).

[e]Effect of diet (P<.01).

[f]Effect of diet (P<.06).

[g]Diet x meal frequency interaction (P<.05).

Trial II

As in Trial I, large differences in nitrogen retention were seen when comparing pigs fed the conventional corn-soy diet with pigs fed the crystalline lysine-supplemented diet (Table 4). Again, reduced nitrogen retention by the pigs fed the lysine-supplemented diets was due to greater urinary nitrogen excretion. Contrary to Trial I, however, no difference in nitrogen retention was found when once or three times per day feeding was compared for those pigs fed the lysine-supplemented diet. The nitrogen retention as a percentage of nitrogen intake was about 10% lower for pigs fed the corn-sesame diet than those fed any other diet in either trial.

These preliminary results suggest that crystalline amino acids should be used with caution in meal feeding intake regimes. The effect of controlled feeding of lysine-supplemented diets should be examined in a growth trial. While these results are of limited importance given the free-choice feeding systems employed in this country, practical implications for limit-fed gestating sows do exist. Studies are underway to determine the effect of meal frequency on the nitrogen metabolism of sows in late gestation.

Table 4. Results of Trial II[a]

Diet	18% C-Soy		18% C-Sesame + Lys	
Meal Frequency	1	3	1	3
Feed intake (lb/d)	1.26	1.26	1.26	1.23
Nitrogen intake (g/d)[b]	15.72	15.72	17.15	16.79
Fecal nitrogen (g/d)	2.02	1.86	1.95	2.05
Urinary nitrogen (g/d)[b]	4.52	4.64	7.53	7.33
Nitrogen retention (g/d)[b]	9.18	9.22	7.67	7.41
Nitrogen retention as % of nitrogen intake[b]	59.9	58.2	44.5	44.0

[a]Each value represents mean of five pigs.

[b]Effect of diet (P<.001).

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December, 1983 1983-6

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Response of Weanling Pigs to Supplementation of Corn-Soybean Meal Diets with Organic Acids and (or) Sodium Bicarbonate

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INTRODUCTION

The post-weaning growth check has been a serious concern to swine producers since the advent of early weaning (i.e., three to four weeks of age) programs in the 1950's. Undoubtedly, the problem is multi-faceted involving interactions between diet, physiological development of the pig, environmental conditions and various other stresses. Using available knowledge from many sources, we have developed a working hypothesis which serves as the basis for current research in our laboratory. This paper discusses some of our concepts.

The early-weaned pig is limited in the ability to produce enzymes to digest complex feedstuffs. Amylase (starch-digesting enzyme) levels are well below adult levels at three weeks of age, then increase rapidly up to eight weeks before leveling off (Hartman et al., 1961; Shields et al., 1980). we hypothesize that this limits the pig's ability to utilize carbohydrates in a corn-soy diet. Work in our laboratory has shown promise for inducing carbohydrase production by administration of hydrocortisone (Chapple et al., 1983). Unfortunately, other complicating factors have limited performance when this compound is administered.

Digestion of plant proteins may be as difficult for the early-weaned pig as the digestion of complex carbohydrates. Milk proteins are degraded quite effectively in the small intestine of the young pig. However, stomach function seems to be more important for digestion of large plant proteins (Catron et al., 1957). Partial hydrolysis by pepsins in the stomach may be essential for these proteins to be fully digested and absorbed. Lewis et al. (1957) and Hartman et al. (1961) showed that pepsin levels are generally very low up to two weeks of age, then increase rapidly up to about six weeks of age.

Four different pepsins have been identified in swine. These are all secreted by mucosal cells of the fundic and pyloric regions of the stomach as inactive precursors (pepsinogens). These zymogen enzyme forms are hydrolyzed rapidly to active pepsins at pH 2 or slowly at pH 3.5. The variation in rate is apparently due to two different pH optima for activation that all pepsinogens possess. Manners (1970) has suggested that pepsins activated at the pH 3.5 optimum may be adequate for digestion of small proteins like casein found in milk. More complex plant proteins, however, may require

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pepsins activated at pH 2 for effective degradation. The ad libitum ingestion of large quantities of dry feed rich in starch and plant proteins immediately after weaning may buffer the stomach pH to levels well above this crucial optimum. Maner et al. (1962) have shown that gastric pH may vary widely depending on the diet fed and the measurement technique employed.

It has been suggested that the low pH of a normal stomach kills bacteria, thus preventing proliferation in the small intestine. These microbes probably reduce the efficiency of nutrient utilization and may be pathogenic under certain conditions. Addition of an acidifying agent to the diet might, therefore, serve an antibiotic-like function by reducing pH and preventing microbial build-up.

There have been limited reports of adding organic acids to weanling pig diets. Reports from Germany by Kirchgessner and Roth (1982) indicated that significant improvements in performance occurred when 1.5 to 2.0% fumaric acid was added to the diet of weanling pigs. Edmonds et al. (cited elsewhere in this publication) found a linear improvement in feed efficiency of weanling pigs fed 0, .75, or 1.5% citric acid. In another trial, however, no significant response to citric acid addition was noted. Organic acids have also been utilized for the preservation of high-moisture grain. Young et al. (1970) reported similar performance by grower pigs fed diets containing dry corn, dry corn + 1.5% propionic acid or high moisture (24%) corn + 1.5% propionic acid. The corrosiveness of organic acids has been the primary limitation to the use of propionic acid as a preservative. Materials resistant to acid degradation must be used for feed preparation, handling and storage.

In contrast, it may be suggested that lowering the pH of the diet may be counterproductive. Apparently, most protein digestion is accomplished by trypsin and chymotrypsin in the small intestine. These enzymes are optimally active at pH above 7. Since the pH of the duodenum and jejunum generally average about 5 and 6, respectively, increasing the buffering of the stomach against low pH might improve protein digestion in the small intestine. Trenkle et al. (1979) quoted Russian work which indicated a significant improvement in performance when 0.9% sodium bicarbonate was added to the diets of weanling pigs.

The first trial described herein was undertaken to determine if alteration of diet pH would significantly affect performance of weanling pigs. The second trial was a comparison of three organic acids for promoting starter pig performance.

EXPERIMENTAL PROCEDURES

Trial I

Ninety-six female pigs were assigned to four treatments arranged as a 2 x 2 factorial within a randomized, complete block design. Four blocks of 20 pigs and one of 16 were assigned to treatments when pigs reached 30 ± 2 days of age. Pigs were randomly assigned from four pig outcome groups established on the basis of weight and litter of origin. Pigs were housed in raised-deck pens within an environmentally controlled nursery. Diets were fed ad libitum and were formulated as shown in table 1. Pigs were removed from the experiment 21 days after initiation of treatments. Gain and feed consumption were measured and gain:feed ratios were calculated weekly by pen, the experimental unit.

Table 1. Composition of Diets Fed in Trial I, %

Diet ingredients	Control	As 1 + 1.5% propionic acid	As 1 + .9% sodium bicarbonate	As 1 + .9% $NaHCO_3$ and 1.5% propionic acid
Corn	73.79	72.29	72.89	71.39
Soybean meal (49%)	23.57	23.57	23.57	23.57
Def. rock phosphate	1.46	1.46	1.46	1.46
Ground limestone	0.73	0.73	.73	.73
Trace mineralized salt	0.35	0.35	.35	.35
Vitamin mix	0.10	0.10	.10	.10
Propionic acid	-	1.50	-	1.50
Sodium bicarbonate	-	-	.90	.90
Total	100.00	100.00	100.00	100.00
Calculated Analysis, %				
Crude protein	17.81	17.68	17.73	17.60
Lysine	.91	.90	.91	.90
Calcium	.82	.82	.82	.82
Phosphorus	.62	.61	.61	.61
Diet pH (avg.)	6.35	4.95	6.60	5.55

Results were evaluated by analysis of variance to establish treatment, replicate and period differences.

Trial II

The second trial involved 192 crossbred pigs assigned to four treatments on the basis of sex, litter of origin and weight per day of age. Sex ratios were constant within the replicates of 24 pigs. Eight replicates of six pigs per pen were assigned to one of the four treatments (table 2) at 30 ± 2 days of age. Parameters measured and analysis were as described for trial I. In addition to analysis of variance, pairwise comparisons were made using the F lsd test.

RESULTS AND DISCUSSION

Trial I

Significant treatment effects were not found in the analysis of this trial (table 3). There was a tendency for pigs fed diets 1 and 2, i.e., control and control + 1.5% propionic acid, respectively, to gain faster and more efficiently than those on diets 3 and 4 which contained sodium bicarbonate. It may be that bicarbonate limited protein digestion in these pigs, but the results are inconclusive. Additionally, pigs tended to consume more of diet 1 than of the acid-treated diets. It was observed that acid-treated diets (2 and 4) emitted a pungent aroma and possessed a bitter taste. Young et al. (1970) found that addition of propionic acid to diets of growing pigs decreased consumption when diets were based on dry corn but increased consumption when high-moisture corn diets were fed.

Table 2. Composition of Diets Fed in Trial II, %

Diet ingredients	Control	As 1 + 2% propionic acid	As 1 + 2% fumaric acid	As 1 + 2% citric acid
Corn	70.71	68.25	68.25	68.25
Soybean meal (49%)	26.62	27.07	27.07	27.07
Def. rock phosphate	1.28	1.30	1.30	1.30
Ground limestone	0.94	0.92	0.92	0.92
Trace mineralized salt	0.35	0.35	0.35	0.35
Vitamin premix	0.10	0.10	0.10	0.10
Propionic acid	-	2.00	-	-
Fumaric acid	-	-	2.00	-
Citric acid	-	-	-	-
Total	100.00	100.00	100.00	100.00
Calculated Analysis, %				
Crude protein	19.00	19.00	19.00	19.00
Lysine	0.99	1.00	1.00	1.00
Calcium	.70	.70	.70	.70
Phosphorus	.60	.60	.60	.60
Diet pH (avg.)	5.78	4.71	4.18	4.06

Trial II

In contrast to trial I, several performance criteria were significantly improved by addition of organic acids to starter pig diets in trial II. Results varied considerably between the first two weeks of the trial and the last two. In weeks 1 and 2, pigs fed fumaric acid at 2% of the diet gained significantly faster than those fed the control diet. Additionally, the feeding of each of the acid-supplemented diets resulted in improved feed efficiency compared to pigs fed the control diet. During weeks 3 and 4, pigs fed diet 1 (control) tended to compensate for poorer performance during weeks 1 and 2. No significant treatment effects were seen, but pigs fed the control diet still tended to gain faster than those fed the acid-treated diets. Differences in feed efficiency were not significant when weeks 3 and 4 were combined, but still tended to favor the acid-fed pigs. Analysis of the performance data for the four-week period showed a significant improvement in feed efficiency by animals fed each acid-supplemented diet versus the control. Daily gains were not significantly different among treatments.

In agreement with the results of trial I, a depression in feed intake was seen when pigs were fed propionic acid-treated diets. This difference was greatest in the first two weeks of the trial but persisted throughout. Apparently, the strong taste and the aroma of propionic acid are objectionable to young pigs. Propionic acid is an aromatic liquid at room temperature, while fumaric and citric acids are dry powders. Poor handling properties and low palatability indicate that propionic acid would not likely be the acid of choice when evaluating organic acids to supplement pig diets.

The significant improvement in gain:feed ratio without increased feed consumption indicate an anabolic response to acidification of diets. Improved

Table 3. Summary of Trial I

	Control	As 1 + 1.5% propionic acid	As 1 + .90% sodium bicarbonate	As 1 + .90% $NaHCO_3$ and 1.5% prop. acid	Std. error of mean
Initial weight (lbs)	21.16	20.06	19.18	19.40	-
Daily gain (lbs)	0.57	0.55	0.51	0.51	.388
Daily feed (lbs)	1.26	1.15	1.19	1.12	.548
Gain/feed	.46	.45	.39	.41	.259

Table 4. Summary of Trial II

	Control	As 1 + 2% propionic acid	As 1 + 2% fumaric acid	As 1 + 2% citric acid	Std. error of mean
<u>Weeks 1 and 2</u>					
Daily gain (lbs)	.273[b]	.295[ab]	.346[a]	.319[ab]	.018
Daily feed (lbs)	.616[a]	.547[b]	.630[a]	.602[ab]	.021
Gain/feed	.412[b]	.502[a]	.536[a]	.503[a]	.025
<u>Weeks 3 and 4</u>					
Daily gain (lbs)	.841	.784	.819	.826	.038
Daily feed (lbs)	1.562	1.399	1.489	1.482	.056
Gain/feed	.527	.564	.547	.555	.015
<u>Overall</u>					
Daily gain (lbs)	.557	.540	.583	.573	.024
Daily feed (lbs)	1.089	.973	1.060	1.042	.034
Gain/feed	.469[b]	.533[a]	.541[a]	.529[a]	.017

[a,b]Means on the same line without a common superscript are different ($P<.05$), determined by F lsd.

protein utilization may account for this improvement if increased pepsinogen activation is occurring. This hypothesis, however, is speculative and further investigations of protein and carbohydrate utilization will be made. Additionally the effect of diet acidification on gastric pH and active pepsin levels should be investigated. Finally, the effects of different acid levels and protein sources will be examined.

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Riboflavin Requirement of Gestating Swine

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Riboflavin, a water-soluble B-vitamin, must normally be added to practical swine diets. In growing swine, a deficiency of riboflavin results in a depression in growth rate (Krider et al., 1949). Riboflavin deficiency in post-pubertal gilts leads to a cessation of estrus without other "outward" deficiency signs (Esch et al., 1980, 1981). During gestation, a deficiency of riboflavin results in premature farrowing, stillbirths and neonatal death losses (Ensminger et al, 1947; Esch et al., 1980). The currently recommended intake of riboflavin for gestating gilts and sows is 5.4 mg per day (NRC, 1979). However, there is little quantitative information on which to base the requirement for riboflavin during gestation.

Traditionally, riboflavin status has been evaluated using rather insensitive criteria such as growth rate, reproductive performance or the riboflavin content of urine and blood. Recently, however, a much more sensitive indicator of riboflavin status has been developed (Nichoalds, 1974). This technique has been accepted as a valid indicator of riboflavin status in humans and laboratory animals. This procedure, the EGR test, is based upon measuring the activity of glutathione reductase, an enzyme present in erythrocytes (red blood cells). Glutathione reductase requires the coenzyme, FAD (flavin adenine dinucleotide), which is one of the active metabolites of riboflavin, in order to be functional. Due to the dependence of the enzyme upon FAD, the activity of the enzyme is related to the amount of FAD within the cell which in turn is dependent upon a sufficient intake of dietary riboflavin. The EGR test is conducted by measuring the activity of glutathione reductase in a preparation of erythrocytes obtained from each animal. The activity of the enzyme is then once again determined for each sample of erythrocytes in the presence of additional FAD to determine the maximal activity of the enzyme. The test results are then expressed as the EGR activity coefficient in the following manner:

$$\text{EGR activity coefficient} = \frac{\text{activity with added FAD}}{\text{activity without added FAD}}$$

A low activity coefficient indicates the animal is receiving adequate riboflavin whereas a high value indicates a riboflavin deficiency.

This experiment was conducted to establish the riboflavin requirement of gestating swine. Forty crossbred gilts were mated and immediately assigned to one of five dietary treatments. The treatments were based on a cornstarch-soybean meal basal diet. The basal diet was supplemented with all nutrients, except

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riboflavin, at levels sufficient to meet the requirements of gestating swine. The basal diet has been previously described and shown to contain approximately .77 ppm of bioavailable riboflavin (Esch et al., 1980, 1981). The five dietary treatments consisted of 1) the unsupplemented basal diet, 2) basal diet + 1 ppm riboflavin, 3) basal diet + 2 ppm riboflavin, 4) basal diet + 3 ppm riboflavin and 5) basal diet + 4 ppm riboflavin. Therefore, these diets contained, respectively, .77, 1.77, 2.77, 3.77 and 4.77 ppm bioavailable riboflavin. Although not all the gilts conceived, no apparent relationship was noted between conception rate and level of dietary riboflavin. Each gilt was confined to an individual gestation stall and fed 1.9 kg (4.2 lb) of its respective diet daily. All gilts were bled at bi-weekly intervals throughout gestation and EGR activity coefficients were determined.

Performance of the gilts is shown in Table 1. Gilts fed the basal diet without supplemental riboflavin farrowed approximately seven days earlier than did those gilts fed the other diets (P<.01). Average daily gain during gestation was significantly lower for gilts receiving the basal diet alone as compared to those fed the other diets. Although litter size was not significantly different among treatments, gilts fed the lowest level of riboflavin gave birth to stillborn piglets, exclusively.

Results of the EGR determinations are presented in Table 2. EGR activity coefficients increased with time in a manner dependent upon the level of dietary riboflavin. The lower the level of dietary riboflavin, the greater the severity of the riboflavin deficiency. Although the EGR data have not been analyzed completely to estimate the riboflavin requirement during pregnancy, it appears that the daily requirement lies somewhere between 5.3 and 7.2 mg assuming an intake of 1.9 kg daily when fed diets containing either 2.77 and 3.77 ppm of bioavailable riboflavin.

Table 1. Gestation and Reproductive Performance of Gilts Fed Different Levels of Riboflavin

Criterion	Bioavailable Riboflavin, ppm .77	1.77	2.77	3.77	4.77
Avg. breeding wt., kg	135.2	128.0	132.0	123.6	132.9
Day of gestation on which gilt farrowed	107.8[a]	114.0[b]	114.9[b]	115.8[b]	115.8[b]
Gestation ADG (to d-109), kg	.37[a]	.58[b]	.62[b]	.63[b]	.58[b]
Gestation ADG (after farrowing), kg	.25[a]	.41[b]	.42[b]	.45[b]	.38[b]
Litter size at farrowing	8.7	10.1	8.4	10.3	9.3
Pig born alive	0[a]	7.4[b]	7.6[b]	9.6[b]	7.6[b]
Stillbirths	8.7[a]	2.7[b]	.8[b]	.7[b]	1.7[b]
Number of gilts	6	7	8	6	6

[a,b]Means followed by different superscripts differ (P<.01).

Table 2. Effect of Riboflavin Deficiency During Gestation on Erythrocyte Glutathione Reductase Activity Coefficient

Days of Gestation	Bioavailable Riboflavin, ppm				
	.77	1.77	2.77	3.77	4.77
7	1.24	1.23	1.26	1.23	1.23
24	1.46	1.39	1.36	1.21	1.18
3C	1.68	1.42	1.42	1.23	1.22
40	1.76	1.46	1.40	1.23	1.17
56	2.17	1.49	1.43	1.18	1.26
70	2.47	1.54	1.37	1.17	1.20
84	2.50	1.62	1.61	1.25	1.20
98	2.94	1.94	1.58	1.19	1.20
Farrowing	3.14	2.05	1.67	1.25	1.28

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December, 1983 1983-8

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Influence of Pre-Rigor Processing, Mechanical Tenderization, Tumbling Method and Processing Time on the Quality and Yield of Ham

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INTRODUCTION

Considerable effort has been put forth since 1970 in an attempt to gain an understanding of the physical, chemical and histological changes in meat associated with or as a result of the mechanical mixing action referred to as "massaging" or "tumbling." A relatively new ham processing innovation of mechanically disrupting the meat tissue structure prior to massaging or tumbling is gaining acceptance (Michels, 1976). This meat disruption process is referred to as "mechanical tenderization" or "masceration" depending on the type of machine used. The mechanical technique and severity of the meat tissue disruption varies due to different machine designs. This disruption of the meat tissue structure would seemingly improve tenderness and allow freer movement of intra- and extracellular materials resulting in improved uniformity in appearance and binding between meat sections. However, no information has been reported to substantiate such assumption.

The objectives of this experiment were to: (1) access the influence of pre-rigor processed meat, mechanical tenderization, tumbling method and processing time on yield and quality of section and formed ham; and (2) identify possible relationships between the uncooked meat tissue characteristics and the subsequent cooked yield.

MATERIALS AND METHODS

Eight market weight hogs with similar genetic and management background were conventionally slaughtered with the resulting sixteen pork carcass sides randomly assigned to one of sixteen treatments (Fig. 1) such that animal variation could be statistically accounted for (Box et al., 1978). Pre-rigor processed ham muscles (semimembranous and biceps femoris) were removed from the carcasses within 10 min after bleeding; whereas, post-rigor processed ham muscles remained intact and were chilled at 2 ± 2°C for 24 hr. The further processing sequence for both pre- and post-rigor ham muscles consisted of trimming, multineedle hand injection of the curing solution, mechanical knife blade tenderization, vacuum tumbling, a processing delay time interval, stuffing, cooking, and chilling. Due to difficulty in accurately separating the adductor muscle from the semimembranous muscle, the two muscles remained joined and were considered as a semimembranous muscle.

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Mechanical tenderization was achieved with a Model IT 2 Belam Mechanical Tenderizer (Belam, Inc., Downers Grove, IL). Tumbling was accomplished with a Universal 190 Inject Star Tumbler (Globus Labs, Hackensack, NJ) operated at 28 rpm with a vacuum of 584-660 mm Hg. The meat was tumbled either continuously or intermittently at 2 ± 2°C with total tumbling revolutions (3,360) and time under vacuum (4 hr) held constant.

After chilling, each muscle was removed from the cooking pouch and casing and allowed to drain for 10 min prior to weighing and cooking yield was calculated. Visual evaluation of the cooked cut surface [3 slices (1.5 cm thick) with the first slice cut 4 cm from the meat section end] of each treatment was performed by a six-member experienced panel for shape uniformity, cure color distribution, cure color intensity and overall appearance according to a nine-point scalar test (9 - extremely desirable). Palatability evaluations of a 2 cm^3 meat portion served at 2 ± 2°C were performed by a six-member experienced taste panel for flavor, tenderness, juiciness and overall satisfaction according to a nine-point hedonic scale (9 - extremely desirable).

The press technique of Wierbicki and Deatherage (1958) was used to measure the water-holding capacity of the processed uncooked meat. Binding strength values were determined as described by Siegel (1976) using a Model TM Instron Universal Testing Machine (Instron Corp., Canton, MA).

RESULTS AND DISCUSSION

Effect of pre-rigor processing

The influences of pre-rigor processing on yield, quality, meat tissue and exudate characteristics are shown in Table 1. Pre-rigor processed ham had significantly greater yield of 1.5% and 2.0% for the semimembranous ($P<0.01$) muscle. Pre-rigor processed meat tissue (uncooked) consistently exhibited higher pH ($P<0.01$) and water-holding capacity values ($P<0.05$).

Effect of mechanical tenderization

Mechanical tenderization improved cooked yields ($P<0.01$) in processed ham muscles by 2.1%(Table 2). All quality characteristics except cure color intensity, overall satisfaction and binding strength were increased in hams processed from the semimembranous muscle (Table 2). Mechanical tenderization improved all palatability charactertistics. Muscle destruction via a mechanical tenderizer increases the availability of salt-soluble proteins for solubilization.

Disruption of meat tissue via a mechanical tenderizer could allow freer movement of intra- and extracellular material of tumbled meat resulting in improved binding between meat chunks. However, there was no difference detected in binding strength due to mechanical tenderization (Table 2).

Effects of tumbling method and processing time

Tumbling method and processing time had no consistent influence on yield, quality and meat tissue characteristics.

In conclusion, pre-rigor processed meat tissue (uncooked) consistently exhibited higher pH and water-holding capacity values with resulting increases in

Table 1. Means and Standard Errors for the Effect of Pre-rigor Processing on Yield, Quality and Meat Tissue of Cured, Mechanically Tenderized, Tumbled and Cooked Pork Semimembranous Muscle

Characteristic	Semimembranous		
	Pre-rigor	Post-rigor	S.E.
Yield (%)	93.1**	91.6	0.44
Appearance evaluation			
Shape uniformity	6.6	6.7	0.40
Cure color intensity	5.6	5.9	0.34
Cure color distribution	5.9	5.4	0.48
Overall appearance	6.3	6.3	0.35
Palatability evaluation			
Flavor	7.3	7.3	0.12
Tenderness	7.4	7.2	0.48
Juiciness	6.9	6.9	0.17
Overall satisfaction	7.2	7.2	0.32
Mechanical evaluation			
Binding strength	0.22	0.23	0.016
Hardness	3.5	3.5	0.15
Meat tissue (before cooking)			
pH	6.4**	6.0	0.10
WHC (% bound)	59.7*	48.4	4.93

* Significant ($P<0.05$)
**Highly significant ($P<0.01$)

cooked yields. However, the pH and water-holding capacity values were not correlated to cooked yields. Mechanical tenderization consistently improved cooked yields. Mechanical tenderization consistently improved cooked yield and palatability characteristics of both muscles, but its influence on appearance characteristics was inconsistent. Increased exudate protein content from mechanical tenderized meat tissue was associated with improved cooked yields. There was no difference in binding strength between meat chunks due to mechanical tenderization. Tumbling method and processing time had little influence on yield, quality, meat tissue and exudate characteristics of cured, mechanically tenderized and cooked pork semimembranous muscle.

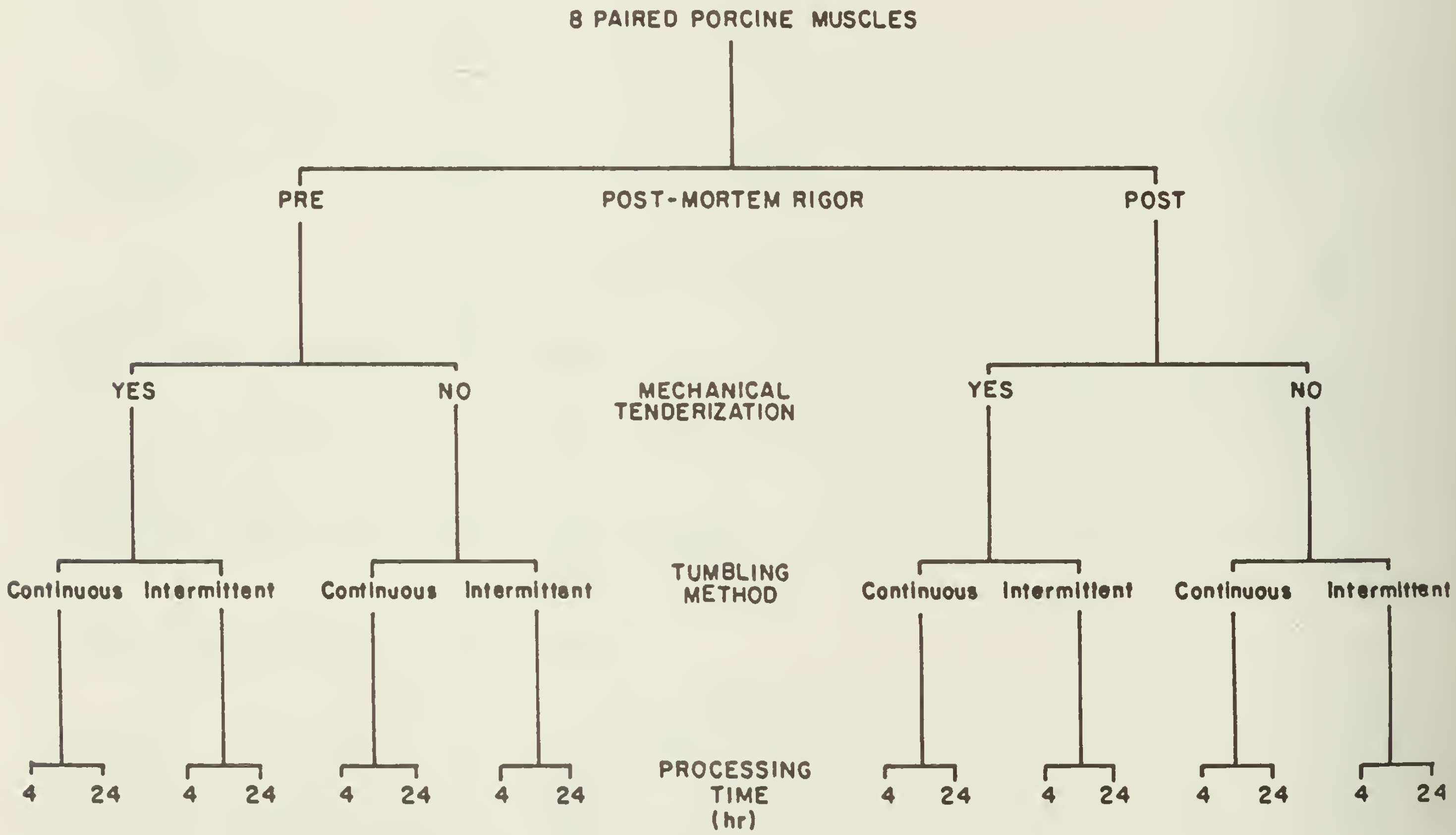

Fig. 1. Experimental Design.

Table 2. Means and Standard Errors for the Effect of Mechanical Tenderization on Yield, Quality and Meat Tissue of Cured, Tumbled and Cooked Pork Semimembranous Muscle

	Semimembranous		
Characteristics	No tenderization	Tenderization	S.E.
Yield	91.3	93.4**	0.44
Appearance evaluation			
Shape of uniformity	6.2	7.1*	0.40
Cure color intensity	5.8	5.8	0.34
Cure color distribution	4.9	6.4**	0.48
Overall appearance	5.6	7.0**	0.35
Palatability evaluation			
Flavor	7.1	7.5**	0.12
Tenderness	6.7	7.9*	0.48
Juiciness	6.7	7.1*	0.17
Overall satisfaction	7.0	7.5	0.32
Mechanical evaluation			
Binding strength	0.21	0.23	0.016
Hardness	3.9	3.2**	0.15
Meat tissue (before cooking)			
pH	6.2	6.2	0.10
WHC (% bound)	56.5	51.6	4.93

* Significant ($P<0.05$)
**Highly significant ($P<0.01$)

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December, 1983

1983-9

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The Effects of Internal Temperature and Thickness on Palatability of Pork Loin Chops

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INTRODUCTION

Many factors influence the consuming public's decisions when selecting fresh meat products. Cost, advertising, appearance and anticipated eating satisfaction are certainly important criteria to evaluate and consider when shopping at the retail market. Once the initial purchase has been made, proper meat cookery becomes important due to its effect on the ultimate palatability characteristics (flavor, juiciness and tenderness) of the end product.

Fresh pork has undergone some criticism for being a rather dry, tough, tasteless product after cooking by the average consumer. A study conducted at the University of Missouri (Hendrix et al., 1963) found that consumers scored 57 percent of the pork chops less than totally acceptable. Of these chops, "not tender enough" was the primary reason cited with "not juicy enough" being the second most mentioned criticism.

Lack of juiciness, flavor and tenderness may be attributed to the traditional high cooking temperature recommendations for pork. Current recommendations for pork cookery suggest an internal doneness temperature ranging from 170°F to 185°F, which corresponds to well done and very well done in beef. Such high recommended temperatures were initially recommended to assure the destruction of any trichina in fresh pork; however, cooking to elevated internal temperatures is not necessary since the thermal death temperature of trichina is 138°F. The cooking of loin chops to a lesser degree of doneness than has been recommended may improve the juiciness, flavor and tenderness of the final product.

The objectives of this study were to determine the effects of internal cooking temperatures and chop thickness on the palatability characteristics of pork loin chops.

MATERIALS AND METHODS

Ten paired loins of similar quality were selected from a group of gilt carcasses that ranged from 170 to 196 pounds. A 15 inch portion of the loin eye muscle (longissimus dorsi muscle) was removed and scored for color, firmness and marbling using the Wisconsin Pork Quality Standards. Loins were frozen in plastic

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lined freezer paper at -40°F for 48 hours and then cut (while frozen) into chops .5, .75 and 1 inch in thickness. Chops of identical thicknesses from individual animals were randomly assigned across temperature treatments of 140, 160 and 175°F so that all animals were represented once per temperature by thickness treatment. The experimental design was a 3 x 3 factorial with 10 replicates per cell. Chops were trimmed to .25 inches of external fat, individually wrapped and placed back into the freezer.

Chops for sensory panel evaluation were thawed 24 hours at 45°F, weighed and cooked over pans in a preheated 350°F South Bend convection oven to the appropriate doneness temperature. Chops were removed, weighed and wrapped in aluminum foil until served (approximately 5 minutes) to a six member experienced taste panel for evaluation of sensory characteristics. Tenderness, juiciness, pork flavor intensity, off flavor intensity and overall acceptability were scored on a continuous scale ranging from 0 to 15, where 0 = extremely tough, dry, bland, unacceptable or extreme off flavor, and 15 = extremely tender, juicy, flavorful, acceptable or no off flavor. All samples from one animal were cooked per taste panel session to eliminate day to day variation in taste panel scores. Chops were placed into the oven according to predetermined cooking times to insure that all chops reached the desired doneness temperature within a reasonable time period.

Total cooking loss was calculated as the percentage change in raw chop weight upon cooking, and was further divided into drip (difference in pan weight as a percentage of raw chop weight) and evaporative (percent total cooking loss minus percent drip loss) losses.

Chops for determination of Warner-Bratzler shear value and proximate analysis were thawed 24 hours at 45°F, cooked to the desired internal doneness temperature and allowed to cool to room temperature. The greatest possible number of .5 inch cores were removed and sheared as many times as possible to obtain the reported mean shear value. The remaining portion of each chop was ground twice through a .2 inch plate for moisture determinations via the method described by Koniecko (1979) and fat determinations via a modified soxhlet extraction.

Fresh tissue samples were thawed overnight prior to pH determination (Koniecko, 1979) and percent bound water determination (Wierbicki and Deatherage, 1958).

Results of the sensory evaluation and the physical and chemical analysis were analyzed using the Statistical Analysis System (SAS, 1982) for analysis of variance and Duncan Mean Separation Analysis.

RESULTS AND DISCUSSION

Means and standard errors of measurements taken on raw muscle samples from the ten paired loins are listed in table 1. Means for marbling and color were very close to the ideal value of 3, but firmness scores were slightly lower (Wisconsin Pork Quality Standards, 1963). The mean pH value for all loins was 5.38 ± .16, while the mean percent bound water was 62.46 ± 4.31. These values suggest that the loins used in this study were relatively free from characteristics typical of pale, soft and exudative pork.

Means and standard errors for cooking losses, sensory panel ratings, partial proximate analysis and shear force values of chops cooked to 140, 160 and 175°F are presented in table 2. Cooking temperature had a significant influence on cooking losses and in perceived and actual moisture content of the cooked chops, with higher temperatures creating greater cooking losses and a drier final product. These results agree with results reported by Weir et al. (1963), Webb et al., (1969) and Pengilly and Harrison (1970). Taste panel members found chops cooked to higher temperatures to be less tender at each treatment level, while shear values indicated that only those chops cooked to 175°F were significantly less tender. Heat may cause both the tenderization and the toughening of meat. In general, those heat induced changes in proteins that result in coagulation and hardening reduce tenderness. Such changes occur in pork retail cuts that originate from an area of support and possess limited amount of connective tissue.

Pork flavor as perceived by taste panel members was significantly more intense at each treatment level as doneness temperatures increased from 140 to 175°F. Webb et al. (1969) attributed higher flavor scores to the pre-conditioning of panel members to prefer the pork flavors developed at higher cooking temperatures since pork has traditionally been prepared at high temperatures. It was apparent in this study that greater surface browning occurred on chops cooked to the higher temperatures. Several researchers and organizations suggest that to achieve the best flavor development and a complete conversion of pigment to the denatured (brownish-gray) form, fresh pork must be cooked to 170°F internally. The release of more flavor components due to increased fat solubilization at higher temperatures may contribute to improved pork flavor at higher cooking temperatures.

Although chops differed significantly in tenderness, juiciness and flavor scores, no significant differences in overall acceptability were found. It appears that the increased tenderness and juiciness derived from lower degrees of doneness were possibly offset by the higher flavor scores of those chops cooked to the higher degree of doneness.

Table 3 shows the effect of the three thickness treatments on various traits of cooked chops. Tenderness, shear value, juiciness and off flavor intensity were not significantly affected by thickness.

Pork flavor intensity and overall acceptability scores were significantly different with the 1 inch chops being scored as more flavorable than both groups of thinner chops. The amine groups of muscle proteins react with reducing sugars (such as free glucose) during the cooking process and a sugar-amine browning product results. This reaction takes place at high temperatures (approximately 190°F) and would occur on the outside surfaces of the chops as they were being prepared for taste panel evaluation. The thicker chops were cooked for a longer period of time to reach the designated internal cooking temperature; consequently, the opportunity for greater sugar-amine production occurred which may have contributed to higher pork flavor intensity scores in the thicker chops.

Differences in total cooking losses were not significant. However, the .5 inch chops had significantly less drip loss and more evaporative loss since evaporative loss was calculated by difference between total cooking loss and drip loss. Greater drip loss in the thicker chops may be attributed to increased cooking time to reach the desired internal temperature. The outer edges of the thick chops were more well done than those of the .5 inch chops and would therefore, have greater drip loss.

SUMMARY

The objectives of this study were to determine the effects of internal cooking temperature and chop thickness on the palatability characteristics of pork loin chops. Ten paired loins of similar quality were selected from a group of gilt carcasses, frozen for 48 hours and then cut into chops .50, .75 and 1 inch thick. Chops for sensory evaluation were prepared in a South Bend convection oven and cooked to internal temperatures of 140, 160 and 175°F. A six member experienced taste panel evaluated the sensory characteristics of tenderness, juiciness, pork flavor intensity, off flavor intensity and overall acceptability. Drip loss, evaporation loss, total cooking loss, percent moisture, percent lipid and Warner-Bratzler shear values were determined by objective methods.

Taste panel results indicated that chops were less tender and less juicy as internal temperature increased from 140 to 175°F. On the other hand, pork flavor as perceived by taste panel members was significantly more intense with increased cooking temperature. Warner-Bratzler analysis revealed that chops cooked to 175°F were significantly less tender.

Pork flavor intensity and overall acceptability scores were significantly different with the 1 inch chops being more desirable than .50 and .75 inch chops. Differences in total cooking losses were not significant; however, the .50 inch chops had less drip loss and more evaporative loss.

This study suggests that pork loin chops should be cut 1 inch thick and cooked to an internal temperature of 160°F for superior palatability traits.

Table 1. Mean and Standard Error Values of Raw Pork Loin Muscle Characteristics

Trait	Mean	Standard error
pH	5.38	± .050
Marbling[a]	2.90	± .155
Color[a]	2.90	± .095
Firmness[a]	2.55	± .110
Bound water (%)[b]	62.46	± 1.363

[a]Based on the Wisconsin Pork Quality Standards. Special Bulletin No. 9. Experimental Station and Extension Service, College of Agriculture, University of Wisconsin - Madison. Color: 1 = pale, grayish-white, 3 = grayish-pink, 5 = dark red. Marbling: 1 = practically devoid, 3 = modest, 5 = abundant. Firmness: 1 = extremely soft and watery, 3 = moderately firm and dry, 5 = very firm and very dry.

[b]Determined according to formula suggested by Wierbicki and Deatherage (1958).

$$100 - \frac{(\text{total moisture area - meat film area}) \times 61.1}{\text{total moisture (mg) in meat sample}} \times 100$$

Table 2. Mean and Standard Error Values for Various Traits of Pork Loin Chops Cooked to Three Internal Temperatures

	(°F)			
Trait	140	160	175	Standard error
Drip loss (%)[d]	1.79[a]	3.01[b]	4.40[c]	± .15
Evaporation loss (%)[d]	19.83[a]	26.64[b]	32.31[c]	± .62
Total cooking loss (%)[d]	21.62[a]	29.32[b]	36.68[c]	± .61
Tenderness[e]	10.90[a]	10.15[b]	8.49[c]	± .18
Juiciness[e]	11.77[a]	9.69[b]	6.96[c]	± .24
Pork flavor intensity[e]	8.51[a]	9.93[b]	11.40[c]	± .21
Off flavor intensity[f]	11.76[a]	12.33[a,b]	13.10[b]	± .19
Overall acceptability[e]	8.77[a]	9.39[a]	9.06[a]	± .22
Moisture (%)	66.73[a]	63.96[b]	60.27[c]	± .26
Lipid (%)[g]	15.76[a]	17.06[a]	17.47[a]	± .50
Warner-Bratzler shear value[h]	7.64[a]	7.69[a]	9.56[b]	± .37

[a,b,c] Mean values in the same column bearing unlike superscripts differ significantly ($P<.05$).

[d] Cooking losses calculated as a percentage of raw chop weight.

[e] Means derived from sensory panel scores with range 0 to 15 where 0 = extremely tough, dry, bland, or unacceptable, and 15 = extremely tender, juicy, flavorful, or acceptable.

[f] Means derived from sensory panel scores with range 0 to 15 where 0 = extreme off flavor and 15 = no off flavor.

[g] Dry matter basis.

[h] Pounds per .50 inch core.

Table 3. Mean and Standard Error Values for Various Traits of Three Thicknesses of Cooked Pork Loin Chops

	Thickness (in.)			
Trait	.50	.75	1.00	Standard error
Drip loss (%)[c]	2.51[a]	3.24[b]	3.45[b]	±.15
Evaporation loss (%)[c]	27.30[a]	26.89[a,b]	24.59[b]	±.62
Total cooking loss (%)[c]	29.82[a]	29.76[a]	28.04[a]	±.61
Tenderness[d]	9.96[a]	9.77[a]	9.81[a]	±.18
Juiciness[d]	9.20[a]	9.34[a]	9.87[a]	±.24
Pork flavor intensity[d]	9.68[a]	9.73[a,b]	10.44[b]	±.21
Off flavor intensity[e]	12.31[a]	12.06[a]	12.82[a]	±.19
Overall acceptability[d]	8.70[a]	8.79[a]	9.73[b]	±.22
Moisture (%)	62.14[a]	64.14[b]	64.67[b]	±.26
Lipid (%)[f]	17.24[a]	16.98[b]	16.07[b]	±.50
Warner-Bratzler shear value[g]	8.42[a]	8.32[a]	8.14[a]	±.37

[a,b] Mean values in the same column bearing unlike superscripts differ significantly.

[c] Cooking losses calculated as a percentage of raw chop weight.

[d] Means derived from sensory panel scores with range 0 to 15 where 0 = extremely tough, dry, bland, or unacceptable, and 15 = extremely tender, juicy, flavorful, or acceptable.

[e] Means derived from sensory panel scores with range 0 to 15 where 0 = extreme off flavor and 15 = no off flavor.

[f] Dry matter basis.

[g] Pounds per .50 inch core.

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December, 1983 1983-10
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Feed Additive Studies with Newly Weaned Pigs: Efficacy of Copper, Antibiotics and Citric Acid

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INTRODUCTION

There are many factors which affect the manner in which pigs respond to antibacterial feed additives. Two such factors are age of the pig and disease level in the environment. The beneficial effects of antibacterial feed additives have been well documented (Cromwell, 1983; Jones and Tarrant, 1982; Moser, 1982). Some studies have shown particularly positive results from feeding high levels (250 ppm) of copper (Phelps, 1983; Kornegay, 1983; Moser, 1982). Recently, studies have been conducted that show good additivity between antibiotics and copper sulfate (Cromwell et al., 1981; de Lima et al., 1981; Roof and Mahan, 1982; Stahly et al., 1

In addition to antibiotics and copper sulfate, organic acids have received considerable attention as feed additives for weanling swine (Kirchgessner and Roth, In fact, citric, fumaric or lactic acid are beginning to find their way into swine diets at levels ranging from 15 to 40 pounds per ton in various countries in Europe and Southeast Asia.

The weanling pig is especially susceptible to stress. The changes that pigs incur following weaning include: (1) change of diet; (2) new pen mates and (3) adaptation to a new environment. As a result, many pigs tend to have a postweaning slump due to the stress that is involved at this particular time. The objectives of our studies were to determine the relationships between antibiotics, copper sulfate and citric acid during the first three weeks after pigs are weaned (eg., from four to seven weeks of age). Performance as well as liver copper accumulation were monitored such that interactions could be assessed.

EXPERIMENTAL PROCEDURE

Four experiments were conducted utilizing 550 pigs weaned at four weeks of age. The pigs were maintained in an environmentally controlled nursery in pens with expanded metal floors. Pigs at weaning were allotted to treatments from outcome groups based on ancestry and weight in a randomized complete block design. Experimental diets were fed to five replicates (pens) of five pigs each in Exp. 1 and 2, three replicates of five pigs in Exp. 3, and four replicates of five pigs in Exp. 4. Average initial weights of the pigs were 19.1, 18.8, 19.2 and 15.2 lb. for Exp. 1 to 4, respectively. Diets and water were provided ad libitum. Weight gain and feed consumption were monitored weekly during the experimental periods of 21 days for each trial.

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The experimental diets (Table 1) were formulated to meet or exceed the nutrient requirements of the 10- to 25-pound pig (NRC, 1979). Each diet contained 19% crude protein. Dietary additions of copper sulfate, antibiotics and citric acid were made at the expense of cornstarch. In addition to weight gain and feed intake data, liver biopsies were obtained surgically at the conclusion of Exp. 1, 3 and 4. In Exp. 1, the median pig was chosen from each pen fed the basal and those treatments containing copper. In Exp. 3 and 4, the three most uniform pigs were chosen from pens involving treatments containing copper. The liver samples were wet ashed and analyzed for copper content by atomic absorption spectrophotometry.

Performance data were analyzed by analysis of variance procedures (Steel and Torrie, 1980). Orthogonal single degree-of-freedom comparisons were used to test treatment differences. Liver data were analyzed by the FLSD method.

RESULTS

The results of trial 1 are presented in Table 2. ASP-250 addition to the diet resulted in improved feed utilization (G/F) at three weeks regardless of citric acid or copper presence in the diet. Copper addition improved both rate and efficiency of weight gain of pigs fed the experimental diets for either one or three weeks. The magnitude of response to copper was, moreover, considerably greater than that which resulted from ASP-250. The statistically significant copper X ASP interaction for gain at either one or three weeks can be interpreted as indicating that copper was more efficacious in the presence than in the absence of ASP - or alternatively, ASP was more efficacious in promoting growth when fed with copper than when fed by itself.

The response to citric acid at .75% of the diet in trial 1 was extremely variable. Clearly, it did not stimulate weight gain. Also clear was the finding that presence of citric acid had no influence on the copper or ASP response. There was a tendency for gain/feed to be improved as a result of citric acid supplementation, although this effect was not statistically significant.

Liver copper concentration was increased ($P<.05$) markedly by addition of 250 ppm copper to the diet. Neither ASP-250 nor citric acid in the diet influenced liver copper accumulation, although numerical means were greater for livers from pigs fed citric acid than from those not fed this organic acid.

In trial 2 (Table 3), all diets contained 250 grams/ton of ASP-250. The gain response to citric acid in this trial was again highly variable at both one and three weeks after initiation of the trial. Copper, on the other hand, effected a marked growth response, especially at one-week postweaning. Relative to control values, the copper-induced growth response was 75% at one week and 11% at three weeks. The statistically significant copper X citric acid interaction present in the gain data implies that copper was more efficacious in promoting weight gain when added to diets containing .75% citrate than when added to diets containing 1.50% citrate. An explanation for this result is not apparent.

The trend for citric acid to enhance efficiency of weight gain in trial 1 was confirmed in trial 2, where gain/feed was increased linearly ($P<.05$) at three weeks as a result of citric acid being added incrementally to the diet. Pigs fed 1.5% supplemental citric acid exhibited a 12.6% feed efficiency response over control animals. This response occurred in the presence of ASP-250 and was uninfluenced by presence or absence of copper in the diet.

Trial 3 had a 2 x 2 x 2 factorial treatment arrangement wherein tylosin (100 grams/ton), sulfamethazine (100 grams/ton) and copper (250 ppm) were evaluated singly and in all combinations. The most consistent and marked response in both rate and efficiency of weight gain occurred with copper sulfate: an 85% and 32% copper response in gain and gain/feed, respectively, at one week on trial; and a 36% and 8% response in gain and gain/feed, respectively, at three weeks on trial.

There appeared to be additivity between tylosin and copper in the performance data, although the interaction between these two was not statistically significant. Nonetheless, both copper and tylosin stimulated rate and efficiency of gain, and the combination tended to be more efficacious than either ingredient alone. Not unexpectedly, sulfamethazine did not enhance performance, nor did it in any way antagonize the efficacy of either copper or tylosin. At both one and three weeks, tylosin was more consistently efficacious in stimulating feed efficiency than in stimulating weight gain. Neither tylosin nor sulfamethazine, alone or in combination, significantly affected liver copper accumulation in pigs fed 250 ppm supplemental copper.

Trial 4 was designed to retest the combination of ASP-250 and copper during the one-week postweaning stress period as well as during a three-week postweaning period (Table 5). As in trial 1, ASP-250 was without benefit when fed to pigs during the one-week postweaning stress period. Copper, on the other hand, stimulated both rate and efficiency of gain markedly during this period. For the three-week period of growth, similar results occurred, although here, ASP-250 produced a response (not statistically significant), but one lower in magnitude than that obtained with copper. In contrast to the results of trial 1, no additivity was present for copper and ASP-250 in this trial. Also, liver copper concentration of pigs fed 250 ppm supplemental copper was not meaningfully affected by presence in the diet of ASP-250.

DISCUSSION

Supplementation of swine diets with 250 ppm copper (from $CuSO_4 \cdot 5H_2O$) markedly and consistently improved rate and efficiency of gain of weanling pigs, particularly during the one-week postweaning stress period. The responses to antibiotics or antibiotic combinations were more variable, as has been noted often in previous work from a variety of investigators. In general, additivity was found when antibiotics were fed in combination with copper. This, too, agrees with recent work published from Minnesota (Moser, 1982), Kentucky (Cromwell, 1983) and Ohio (Roof and Mahan, 1982) stations.

It is generally agreed that 250 ppm copper is the most efficacious level to feed to weanling pigs. The United States FDA has chosen not to regulate copper usage in either poultry or swine diets. Nonetheless, commercial swine feeds or supplements seldom provide for more than 125 ppm copper. This is so because the feed manufacturer must consider the possibility that swine producers may add additional copper to their finished swine feed, thereby risking copper toxicity (500 ppm copper can be toxic to pigs). The European Economic Community (EEC) recently established regulations for copper usage in swine feeds manufactured in the EEC countries; ie., 200 ppm up to four months of age, and 125 ppm thereafter. Dr. R. Braude, the discoverer of copper's growth-enhancing properties in pigs

(Braude, 1948) has emphatically criticized this ruling, claiming the 250 ppm level to be safe and optimum in terms of improved rate and efficiency of weight gain (cf. Phelps, 1983).

The failure of sulfamethazine (the same granulated product used in Elanco's Tylan-Sulfa product) to exhibit growth-promoting efficacy was not surprising. Sulfamethazine is a relatively inexpensive gram-negative antibacterial drug that exhibits good efficacy against Bordetella organisms that invade the nasal cavities and cause atrophic rhinitis. Because sulfamethazine is orally active and gets to the nasal cavity of pigs in significant concentration, one can easily justify inclusion of sulfamethazine (or another orally active sulfa drug) as a rhinitis preventative. Interestingly, however, sulfamethazine is not cleared for use in swine feeds except in combination with antibiotics like tylosin (tylosin-sulfa) or chlortetracycline plus penicillin (ASP-250). Obviously, therefore, the copper + sulfamethazine combination could not be legally fed to swine. On the other hand, the copper + ASP-250 or copper + tylosin-sulfa can be legally fed to swine in the United States.

Very little work has been published wherein liver copper stores have been evaluated after having been fed supplemental copper for a three- or four-week postweaning growth trial. Our data in which liver biopsy samples were obtained provided no clear evidence that any of the antibiotics, sulfamethazine or citric acid had any consistent effect on liver copper stores. Roof and Mahan (1982) came to a similar conclusion regarding effects of 55 ppm carbadox on accumulation of copper in the liver of pigs fed supplemental copper. Nonetheless, carbadox was observed to significantly increase fecal copper excretion in pigs fed 250 ppm copper. Because swine feces may be reconsumed by other species of livestock, or by pigs themselves, it is of interest to speculate on the relative bioavailability of copper when present in feces compared with that provided as $CuSO_4 \cdot 5H_2O$. Preliminary evidence from our laboratory suggests that fecal copper (from feces obtained with pigs fed 250 ppm copper) is much less bioavailable to chicks than is copper consumed as copper sulfate.

Liver copper concentration was found to be extremely variable - even for pigs fed the same diet in the same pen. Ten- to 15-fold differences existed for copper-fed pigs in the same pens. We are currently looking into the relevance of this finding. In particular, we are interested in whether pigs that seem most inclined to accumulate copper in their livers are those that respond best or poorest to supplemental copper feeding.

The work reported here with either .75% or 1.5% supplemental citric acid indicates that more work is needed in this area of investigation. It is likely that either or both of these additions functioned to reduce the pH of the diet. Whether this phenomenon or something else accounts for the apparent citric acid-enhancing effect on feed conversion remains to be determined. Also, other organic acids should be tested as well. In particular, fumaric acid and lactic acid deserve attention. Work from R. A. Easter's laboratory (Giesting and Easter, 1983), in fact, shows good efficacy from adding 2% fumaric acid to diets for weanling pigs.

SUMMARY

Marked and consistent gain and feed efficiency responses occurred upon supplementing weanling pig diets with 250 ppm copper, particularly during the

postweaning stress period (ie., from weaning at four weeks of age to one-week postweaning). Antibiotics or antibiotic combinations were less efficacious than copper during the first week postweaning. During either a one-week or a three-week postweaning growth period, the antibiotic preparations, ASP-250, tylosin or tylosin-sulfamethazine were generally additive with copper in promoting increased rate and/or efficiency of weight gain. Liver copper concentration was increased by dietary copper supplementation, but there was no clear evidence that any of the antibiotic preparations affected the level of copper deposited in the liver. Citric acid supplementation at either .75% or 1.50% of the diet increased feed efficiency, with the response occurring in both the presence and absence of 250 ppm copper and/or 250 grams/ton ASP-250. Liver copper accumulation in pigs fed 250 ppm copper was increased slightly but not statistically significantly as a result of feeding .75% citric acid. Liver copper levels obtained by a surgical liver biopsy procedure revealed extreme variability, even among pigs fed the same diet in the same pen.

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Table 1. Percentage composition of basal diets[a]

Ingredient	%
Cornstarch	1.10
Ground yellow corn (8.5% CP)	64.77
Soybean meal (49% CP)	22.08
Dried whey (12% CP)	7.00
Fish meal (61% CP)	3.00
Dicalcium phosphate	.70
Ground limestone	.80
Trace-mineral mix[b]	.35
Vitamin mix[c]	.20

[a]Contained 19% CP.

[b]Contains in percent of mix: selenium, .00286; iodine, .01; copper, .23; manganese, .57; iron, 2.57; zinc, 2.86 and sodium chloride, 84.0.

[c]Contains per pound of premix: vitamin A, 1,500,000 IU; vitamin D_3, 150,000 IU; vitamin E, 10,000 IU; riboflavin, .5 g; niacin, 7.5 g; d-Ca pantothenate, 3.0 g; choline chloride, 75 g and vitamin B_{12}, 8 mg.

Table 2. Performance and liver copper data of trial 1[a]

Diet	Weaning through 1 week			Weaning through 3 weeks			Liver copper[b]
	ADG, lbs[de]	ADF, lbs	Avg. G/F[d]	ADG, lbs[cde]	ADF, lbs[cde]	Avg. G/F[cd]	ppm dry tissue
1. Basal (B)	.16	.48	.333	.57	1.16	.491	17[b]
2. B + .25% ASP-250[f]	.08	.51	.157	.53	1.02	.520	--
3. B + .10% $CuSO_4 \cdot 5H_2O$[g]	.19	.44	.432	.61	1.08	.565	369[a]
4. As 2 +3	.42	.61	.689	.79	1.37	.577	334[a]
5. As 1 + .75% citric acid[h]	.14	.44	.318	.53	1.01	.525	--
6. As 2 + .75% citric acid	.15	.42	.357	.60	1.10	.545	--
7. As 3 + .75% citric acid	.31	.52	.596	.65	1.21	.537	437[a]
8. As 4 + .75% citric acid	.26	.48	.542	.78	1.26	.619	489[a]
Pooled SEM	.020	.026	.011	.020	.025	.001	

[a]Data are means of five replicates of five pigs each; average initial weight was 19.1 pounds.

[b]Data are means of five replicates of one pig each; the pooled SEM from the transformed (ln (Y+1)) data was .3170772. Means in the same column bearing different supercripts differ ($P<.05$).

[c]ASP-250 main effect was significant ($P<.05$) for gain and gain/feed and for feed intake ($P<.08$) at three weeks.

[d]Copper sulfate main effect was significant ($P<.001$) for gain and gain/feed at both one and three weeks and for feed intake ($P<.001$) at three weeks.

[e]ASP-250 X copper sulfate interaction was significant ($P<.06$) for gain at one week and for gain and feed intake ($P<.04$) at three weeks.

[f]ASP-250 provides 100 g/ton chlortetracycline, 100 g/ton sulfamethazine and 50 g/ton penicillin.

[g]Provides 250 ppm copper.

[h]Provided as free acid (anhydrous).

Table 3. Performance data of trial 2[a]

Diet	Weaning through 1 week			Weaning through 3 weeks		
	ADG, lbs[bd]	ADF, lbs[bd]	G/F[bd]	ADG, lbs[cd]	ADF, lbs[bd]	G/F[c]
1. Basal + .25% ASP-250[e]	.20	.49	.408	.54	1.10	.491
2. As 1 + .75% citric acid[f]	.13	.43	.302	.49	.97	.505
3. As 1 + 1.50% citric acid	.31	.59	.525	.71	1.28	.555
4. As 1 + .10% $CuSO_4 \cdot 5H_2O$[g]	.33	.57	.579	.56	1.13	.496
5. As 2 + .10% $CuSO_4 \cdot 5H_2O$	.45	.73	.616	.71	1.35	.526
6. As 3 + .10% $CuSO_4 \cdot 5H_2O$	.34	.61	.557	.66	1.19	.555
Pooled SEM	.023	.021	.012	.023	.031	.001

[a]Data are means of five replicates of five pigs each; average initial weight was 18.85 pounds.

[b]Copper sulfate main effect was significant ($P<.005$) for gain, feed intake and gain/feed at one week and ($P<.07$) for feed at three weeks.

[c]Citric acid main effect was significant ($P<.05$) for gain and gain/feed at three weeks.

[d]Copper sulfate X citric acid interaction (.75% vs. 1.50% X Cu) was significant for gain, feed intake and gain/feed at one week ($P<.07$) and for gain and feed intake at three weeks ($P<.02$).

[e]ASP-250 provides 100 g/ton chlortetracycline, 100 g/ton sulfamethazine and 50 g/ton penicillin.

[f]Provided as free acid (anhydrous).

[g]Provides 250 ppm copper.

Table 4. Performance and liver copper data of trial 3[a]

Diet	Weaning through 1 week			Weaning through 3 weeks			Liver copper[b]
	ADG, lbs[d]	ADF, lbs[d]	G/F[cd]	ADG, lbs[d]	ADF, lbs[d]	G/F[cd]	ppm dry tissue
1. Basal (B)	.20	.46	.435	.51	1.04	.490	--
2. B + 100 g/ton sulfamethazine	.21	.47	.447	.52	1.03	.505	--
3. B + 100 g/ton tylosin	.34	.58	.586	.60	1.15	.522	--
4. As 2 + 3	.31	.52	.596	.60	1.11	.541	--
5. As 1 + .10% $CuSO_4 \cdot 5H_2O$[e]	.45	.68	.662	.75	1.30	.577	303[a]
6. As 2 + .10% $CuSO_4 \cdot 5H_2O$	.52	.80	.650	.71	1.39	.511	290[a]
7. As 3 + .10% $CuSO_4 \cdot 5H_2O$	.48	.68	.706	.80	1.42	.563	330[a]
8. As 4 + .10% $CuSO_4 \cdot 5H_2O$	.51	.73	.699	.77	1.35	.570	405[a]
Pooled SEM	.030	.031	.008	.030	.047	.001	107

[a] Data are means of three replicates of five pigs each; average initial weight was 19.2 pounds.

[b] Data are means of three replicates of three pigs each. Means in the same column bearing different superscripts differ ($P<.05$).

[c] Tylosin main effect was significant ($P<.06$) for gain/feed at both one and three weeks.

[d] Copper sulfate main effect was significant ($P<.006$) for gain, feed intake and gain/feed at both one and three weeks.

[e] Provides 250 ppm copper.

Table 5. Performance and liver copper data of trial 4[a]

Diet	Weaning through 1 week			Weaning through 3 weeks			Liver copper[b]
	ADG, lbs[d]	ADF, lbs[d]	G/F[d]	ADG, lbs[d]	ADF, lbs[c]	G/F[d]	ppm dry tissue
1. Basal (B)	.16	.40	.400	.28	.76	.368	--
2. B + .25% ASP-250[e]	.09	.35	.257	.39	.91	.429	--
3. B + .10% $CuSO_4 \cdot 5H_2O$[f]	.23	.45	.511	.42	.87	.483	308[a]
4. As 2 + 3	.26	.51	.510	.41	.93	.441	233[a]
Pooled SEM	.016	.017	.006	.015	.022	.002	69

[a] Data are means of four replicates of five pigs each; average initial weight was 15.2.

[b] Data are means of four replicates of three pigs each. Means in the same column bearing different superscripts differ (P<.05).

[c] ASP-250 main effect was significant (P<.06) for feed intake at three weeks.

[d] Copper sulfate main effect was significant for gain, feed intake and gain/feed at one week (P<.02) and for gain and gain/feed at three weeks (P<.10).

[e] ASP-250 provides 100 g/ton chlortetracycline, 100 g/ton sulfamethazine and 50 g/ton penicillin.

[f] Provides 250 ppm copper.

December, 1983 1983-11

University of Illinois at Urbana-Champaign

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Cooperative Extension Service

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Department of Animal Science

Responses of Pigs in Crowded Environments to Dietary Antimicrobials

A. H. JENSEN, T. F. PARK AND J. D. TRACY

Crowding (Gehlbach et al., 1966) and floor materials (Wilson et al., 1977) were early shown to affect behavior and performance of pigs. And Jensen (1979) found that when four-week-old, weaned pigs were exposed to cold stress, dietary carbadox (supplied by Mecadox) significantly (P<.01) improved rate and efficiency of gain.

This report summarizes data from experiments designed to further evaluate the effects of dietary antimicrobials (carbadox and copper)on gain and feed efficiency of young pigs having inadequate and adequate floor space allowances.

EXPERIMENTAL PLAN

In Experiment I 96 pigs averaging about 16 pounds initial weight were used. Individual pigs, within outsome groups of six based on ancestry and weight, were randomly assigned to treatment. Floor space per pig was either 1.5 or 3.0 square feet and dietary additive was either 55 ppm of carbadox or 220 ppm of copper (provided as copper sulfate), which has been shown to rather consistently result in increased rate of gain. Pigs were confined to stainless steel slotted-floor pens in an environmentally regulated nursery. Each pen had a stainless steel self-feeder and a nipple waterer. The test was for 28 days.

In Experiment II, 352 pigs averaging about 47 pounds were used. From outcome groups of four, based on weight and sex, individual pigs were randomly assigned to treatment. Floor space per pig was either 3.0 or 7.5 square feet and diet contained either 0 or 55 ppm of carbadox. Replicates were confined to units with either totally or partially slotted floor pens in mechanically ventilated units. Each pen had a two-hole metal self-feeder and a nipple waterer. The test was for 38 days.

The basal diets used are shown in table 1.

RESULTS

In Experiment I, average daily gain was higher and average daily feed slightly lower for the pigs having 3.0 square feet of floor space compared to those having only 1.5 square feet (table 2). Average gain/feed value, however, was signifi-

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cantly ($P<.05$) higher when pigs had 3.0 square feet of floor space.

Average daily gain tended to be higher and average daily feed lower when the diet contained either carbadox or copper. But average gain/feed values were significantly ($P<.05$) higher for the diets with either carbadox or copper added.

There were no significant interactions between floor space allowance and dietary antimicrobials.

In Experiment II, floor space allowance did not affect average daily feed intake, but average daily gain ($P<.01$) and average gain/feed values ($P<.001$) were significantly higher when pigs had 7.5 square feet compared to only 3.0 square feet (table 3).

Dietary carbodox tended to result in lowered daily feed intake, but significantly improved average daily gain ($P<.05$) and average gain/feed ($P<.001$).

As in Experiment I, there were no significant interactions between space allowances and dietary feed additive level.

These results in general agree with those of Moser et al., 1982 and Yen and Pond, 1983. In the former, they reported that 20-pound pigs in crowded conditions (1.5 square feet of floor space per pig) receiving ASP-250 in the diet gained as well as those with 2.5 square feet of floor space but not receiving ASP-250. Yen and Pond (1983) found that decreasing floor space per 16-pound pig from 2.75 to 1.44 square feet significantly ($P<.05$) decreased rate of gain. Dietary carbdox (55 ppm) significantly ($P<.05$) increased rate of gain, and appeared to modify the effects of crowding.

SUMMARY

Pigs of 16.5 pounds initial weight and on test for 28 days and pigs of 47.5 pounds initial weight and fed for 38 days responded to floor space allowances and to dietary antimicrobials.

Inadequate floor space decreased rate of gain and gain/feed values, but average daily feed values were not significantly different.

Pigs gained faster and more efficiently when antimicrobials were in the diet irrespective of floor space allowance. On the average, rate of gain and gain/feed values for "crowded" pigs fed a dietary antimicrobial were equal to or better than the adequate-space pigs fed the basal diets. However, highest rate of gain and gain/feed values were obtained with the pigs that had both adequate floor space and a dietary antimicrobial (carbadox or copper sulfate). Average feed intake values were lowest when antimicrobials were fed.

These results indicated that the dietary antimicorbials carbadox (55 ppm) and copper sulfate (220 ppm) modified the effects of crowding. But it would seem ill-advised to expect dietary antimicrobials to totally compensate for an inadequate floor space environment. Indeed, especially with the heavier pigs on test for a longer period of time (Experiment II), maximum performance was realized when both adequate space and dietary carbadox were provided.

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Table 1. Composition of Basal Diets

Item	Expt. I	Expt. II
Ground yellow corn (8.8% C.P.)	46.20	78.55
Soybean meal (48.5% C.P.)	28.00	19.00
Rolled oats (14% C.P.)	20.00	---
Dried whey (12% C.P.)	2.50	---
Dicalcium phosphate	1.75	1.25
Ground limestone	1.00	0.75
TM salt (Se)	0.35	0.35
Illini vitamin mix	0.20	0.10
	100.00	100.00
Calculated:		
Crude protein, %	20.00	16.00
Lysine, %	1.00	.75

Table 2. Summary of Results, Experiment I

	Feed Additive			
Floor space/pig	-	Carbadox[a]	Copper sulfate[b]	
Average initial wt., lbs[c]				Avg.
1.5 sq. ft.	16.7	16.3	16.5	16.5
3.0 sq. ft.	16.1	16.7	16.5	16.4
Average	16.4	16.5	16.5	
Average daily gain, lbs				
1.5 sq. ft.	.48	.57	.57	.54
3.0 sq. ft.	.57	.64	.57	.59
Average	.52	.60	.57	
Average daily feed, lbs				
1.5 sq. ft.	1.43	1.52	1.28	1.41
3.0 sq. ft.	1.45	1.25	1.28	1.33
Average	1.44	1.38	1.28	
Average gain/feed				
1.5 sq. ft.	.336	.375	.445	.385
3.0 sq. ft.	.393	.512	.445	.450[d]
Average[e]	.364	.443	.445	

(Footnotes on next page)

Table 2 Footnotes

[a]55 ppm, supplied by Mecadox.

[b]Provided 220 ppm of copper (Vineland acidified copper sulfate; contained 25.5% copper.

[c]Each value is an average for two pens of eight pigs each. Test was for 28 days.

[d]Gain/feed value greater (P<.05) for pigs with 3.0 square feet of floor space than for those with 1.5 square feet of floor space.

[e]Gain/feed value for control pigs was lower (P<.08) than for those fed diets with a feed additive.

Table 3. Summary of Results, Experiment II

Space per pig	Dietary Carbadox –	Dietary Carbadox +	Avg.
Average initial wt., lb[a]			
3.0 sq. ft.	47	48	47.5
7.5 sq. ft.	47	48	47.5
Average	47	48	
Average daily gain, lb			
3.0 sq. ft.	1.35	1.47	1.41[b]
7.5 sq. ft.	1.44	1.60	1.52[b]
Average[c]	1.39	1.54	
Average daily feed, lb			
3.0 sq. ft.	3.76	3.44	3.60
7.5 sq. ft.	3.75	3.38	3.56
Average	3.75	3.41	
Average gain/feed			
3.0 sq. ft.	.365	.435	.400[d]
7.5 sq. ft.	.371	.483	.427[d]
Average[e]	.368	.459	

[a]Each value is an average of 11 pens of eight pigs each, test period of 38 days.

[b]Effect of space significant (P<.01).

[c]Effect of carbadox significant (P<.05).

[d]Effect of space significant (P<.10).

[e]Effect of carbadox significant (P<.001).

December, 1983 1983-12

University of Illinois at Urbana-Champaign
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High-Oil Corn and Antimicrobials in Diets for Growing Pigs

A. H. JENSEN AND T. F. PARK

High-oil corn (HOC) can be effectively used in diets for pigs of different ages. In addition to the higher oil content (5.5 to 7.5% vs 3.5% in regular corn), it usually has slightly more crude protein and lysine than regular corn.

Two experiments were conducted. Experiment I evaluated lysine supplementation and calorie:lysine ratios in HOC-based diets compared to a regular corn-based diet. Experiment II was designed to determine whether dietary antimicrobial effect(s) would differ between HOC and regular corn diets.

EXPERIMENTAL PLAN

Experiment I

Seventy-two pigs averaging 58 pounds in weight were used. Pigs were allotted to treatment from outcome groups of four based on ancestry, weight and sex. They were confined to partially slotted floor pens in a naturally ventilated unit. Each pen had a metal two-hole self-feeder and a nipple waterer. Dietary treatments were: (1) regular corn-based diet; (2) HOC replaced regular corn in Diet I; (3) Diet II plus synthetic lysine to provide calorie:lysine ratio equal to that in Diet I; and (4) HOC-soybean meal ratio adjusted to provide a calorie:lysine level equal to Diet I. The test was for 42 days. Composition of the diets fed is shown in table 1.

Experiment II

Ninety-six pigs averaging about 23 pounds were used. Outcome groups of eight were formed on the basis of ancestry and weight. Individual pigs within outcome groups were randomly assigned to the eight dietary treatments. Pigs were confined, six per pen, to pens on stainless steel slotted floors in an environmentally regulated nursery. There was a stainless steel self-feeder and a nipple waterer in each pen. The compositions of the regular corn-based and HOC-based diets are shown in table 2. These diets were formulated to have the same calorie:lysine value, and each was supplemented with either no antimicrobial, 20 mg of chlortetracycline per pound, 220 ppm of copper or both chlortetracycline and copper. The test was for 28 days.

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RESULTS

Experiment I.

Average daily gains did not differ significantly among dietary treatments (table 3). Average daily feed intake was lowest with Diet 2 which had the highest calorie content. Diet 3 (.04% synthetic lysine added) and Diet 4 (.04% of lysine supplied by added soybean meal) had calorie:lysine ratios equal to that in Diet 1 but produced slightly higher gains that did Diet 1. Average gain/feed value for the three HOC-based diets (.400) was 6.7% higher than that for the regular corn-based diet.

Experiment II.

The average daily gain ($P<.05$) and average daily feed ($P<.05$) for the pigs fed the HOC-based diets were higher than for those fed the regular corn-based diets (table 4). Average gain/feed values did not differ significantly between corns.

Though the average weight of the pigs receiving the HOC was two pounds heavier initially than the pigs receiving regular corn, this would not likely account for the 25% greater feed intake by the HOC pigs. Perhaps due to their slightly higher fat content the HOC diets may have been more readily accepted, and/or the lower heat increment of fat modified environmental stress - average outside temperature for the test period was 86.4°F, with 18 of the 28 days being 87°F or higher.

Neither dietary chlortetracycline nor dietary copper nor the combination significantly affected performance. Highest gain value was for the combination in the regular corn diet, for copper or the combination in the HOC diets. Daily feed intake values were similar among diets within corns. Gain/feed values for both corns were highest with the copper or the combination additions.

SUMMARY

Pigs averaging about 58 pounds had 6.7% better gain/feed values when fed high-oil corn-based diets than when fed regular corn-based diets for a 42-day period. This occurred whether high-oil corn was substituted for regular corn on an equal weight basis or on equal calorie:lysine ratio basis.

Pigs averaging about 23 pounds fed high-oil corn-based diets had significantly higher daily gain and gain/feed values over a 28-day period than those fed regular corn-based diets when calorie:lysine ratios were similar in all diets. Neither dietary chlortetrecycline, copper sulfate nor a combination of the two significantly affected rate of gain, daily feed intake or gain/feed values. However, gains and gain/feed values were highest when microbials were in the diets. There was no interaction between corns and antimicrobials.

Table 1. Composition of Diets, Experiment I

Item	Diet No. 1	2	3	4
Regular corn[a]	78.35	--	--	--
High-oil corn[b]	--	78.35	78.26	77.20
Soybean meal[c]	19.00	19.00	19.00	20.15
Dicalcium phosphate	1.25	1.25	1.25	1.25
Ground limestone	0.75	0.75	0.75	0.75
T M salt	0.35	0.35	0.35	0.35
Illini vitamin mix	0.10	0.10	0.10	0.10
Aurofac-10	0.20	0.20	0.20	0.20
L-lysine (78%)	--	--	0.04	--
	100.00	100.00	100.00	100.00
Calculated:				
Crude protein, %	16.1	17.0	17.0	17.5
Lysine, %	.76	.77	.80	.80
Gross energy, kcal/lb	1740	1840	1840	1840
Gross energy, kcal/ % lysine	2289	2390	2289	2286

[a]Assumed 8.8% crude protein, .24% lysine, 3.5% fat.

[b]Assayed 10.0% crude protein, .26% lysine, 7.5% fat.

[c]Assumed 48.0% crude protein, 3.0% lysine, 0.5% fat.

Table 2. Composition of Basal Diets, Experiment II

Ingredient	Regular Corn[a]	High-Oil Corn[b]
	%	%
Corn	78.55	77.55
Soybean meal[c]	19.00	20.00
Dicalcium phosphate	1.25	1.25
Ground limestone	0.75	0.75
T M salt	0.35	0.35
Illini vitamin mix	0.10	0.10
Antibiotic[d]	--	--
Copper sulfate[e]	--	--
	100.00	100.00
Calculated, %		
Crude protein	16.1	17.7
Lysine	.76	.84
Gross energy, kcal/lb	1740	1920
Gross energy, kcal/ % lysine	2289	2285

(FOOTNOTES ON NEXT PAGE)

Table 2 Footnotes

[a] Assumed 8.8% crude protein, .24% lysine, 3.5% fat.

[b] Assayed 10% crude protein, .28% lysine, 5.8% fat.

[c] Assumed 48.0% crude protein, 3.0% lysine, 0.5% fat.

[d] Contained 10 grams of chlortetracycline activity per pound.

[e] Contained 25.5% copper from Vineland Acidified Copper Sulfate (86.6% $CuSO_4 \cdot 5H_2O$ and 13.4% anhydrous citric acid).

Table 3. Summary of Results, Experiment I

Diet	1	2	3	4
Corn	Regular	High-oil		
Gross energy/% lysine, kcal	2289	2390	2289	2280
Average initial weight, lb[a]				
Replicate 1	58	58	56	58
Replicate 2	58	58	58	58
Average	58	58	57	58
Average daily gain, lb				
Replicate 1	1.52	1.58	1.65	1.65
Replicate 2	1.54	1.48	1.59	1.47
Average	1.53	1.53	1.62	1.56
Average daily feed, lb				
Replicate 1	4.23	4.06	4.08	4.01
Replicate 2	3.92	3.62	3.82	3.92
Average	4.07	3.84	3.95	3.96
Average gain/feed				
Replicate 1	.358	.388	.405	.410
Replicate 2	.393	.410	.416	.374
Average	.375	.399	.410	.392

[a] Each value is an average for nine pigs. Experiment was for 42 days.

Table 4. Summary of Results, Experiment II

Diet	1	2	3	4	
Additive		Chlor-tetracycline[a]	Copper sulfate[b]	Chlor-tetracycline + copper sulfate[c]	
Average initial wt., lbs[d]					
Regular corn	22.0	22.0	21.0	22.0	22.0
High-oil corn	25.0	25.0	24.0	24.0	24.0
Average	23.0	24.0	23.0	23.0	
Average daily gain, lbs					
Regular corn	.92	.96	.93	1.00	.95
High-oil corn	1.09	1.08	1.22	1.21	1.15[e]
Average	1.01	1.05	1.07	1.10	
Average daily feed, lbs					
Regular corn	2.10	2.11	1.97	2.14	2.08
High-oil corn	2.59	2.62	2.60	2.61	2.60[e]
Average	2.34	2.37	2.29	2.38	
Average gain/feed					
Regular corn	.442	.452	.468	.466	.457
High-oil corn	.420	.412	.469	.464	.441
Average	.431	.432	.469	.465	

[a]Twenty mg of activity per pound of diet.

[b]Two hundred ppm of copper added to the diet.

[c]Twenty mg of antibiotic activity per pound plus 200 ppm of copper.

[d]Each value is an average for two pens of six pigs each.

[e]Average daily gain and average daily feed values were higher ($P<.05$) for high-oil corn diets than for regular corn diets.

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Utilization of Dehulled Sunflower Seeds by Growing Pigs

C. C. LIN AND A. H. JENSEN

Sunflower seeds can be used as a source of supplemental energy in swine diets, but for the young pig the high fiber level would limit the level used. Pelleting improved utilization of diets containing up to 26% sunflower seeds (Adams et al., 1982).

Since sunflower seeds contain, on the average, about 29% crude fiber, which pigs cannot effectively utilize, two experiments were conducted to evaluate dehulled sunflower seeds (DSFS) as a source of supplemental energy in diets for growing pigs. The DSFS assayed 50.5% fat.

MATERIALS AND METHODS

In Experiment I 56 pigs weaned at 28 days of age and averaging about 21 pounds in weight were used. They were housed in an environmentally regulated nursery having stainless steel slotted floor pens. There was a self-feeder and a nipple waterer in each pen. There were two pens of seven pigs each per dietary treatment and the feeding period was for 28 days.

Experiment II involved 96 crossbred pigs averaging about 45.0 pounds in weight. They were housed in a mechanically ventilated, partially slotted floor building. Feed and water were available ad libitum. The feeding period was limited to 14 days because of diet supply.

Composition of the diets are shown in table 1. In diets II and III the ground DSFS replaced 5 and 10%, respectively, of the corn. Diet IV was formulated to have 10% DSFS and also have the same calorie:lysine ratio as Diet I.

RESULTS

The results are shown in tables 2 and 3. In Experiment I, rate of gain during the first 14 days appeared to increase as level of DSFS increased. Feed intake was higher with the DSFS diets and highest gain/feed values were from the 10% DSFS diets.

For the entire 28-day period, average daily gain was significantly (P<.01) higher by the pigs receiving the DSFS diets, with the highest value by the pigs receiving Diet IV which had a calorie:lysine ratio similar to Diet I. Average

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feed intake values did not differ significantly among dietary treatments, but gain/feed was improved ($P<.08$) when DSFS meal was in the diet.

Average daily energy intake increased as level of DSFS increased. Average values of energy per unit of gain were not significantly different.

In Experiment II, for the 14-day period average daily gain values were significantly ($P<.05$) higher with the 10% DSFS diets. Feed intake was similar for all diets. Gain/feed values were higher ($P<.01$) for the DSFS diets than for the control diet (I).

Average daily energy intakes were highest on the 10% DSFS diets, but energy per unit of gain was similar for all diets.

SUMMARY

Although these experiments were of relatively short duration (28 or 14 days), the results showed that the diets were readily accepted by 28-day-old pigs and by 45-pound pigs. Daily gain tended to be higher and gain/feed values significantly higher when the diet contained DSFS. The fat in the DSFS was apparently efficiently used by the pig.

The dehulled sunflower seeds were easily ground and incorporated into the diets. They could be a viable alternative source of supplemental fat for use in swine diets.

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Table 1. Composition of Diets Fed

Item	Diet Number I	II	III	IV
Corn	77.85	72.85	67.85	68.85
Soybean meal	19.50	19.50	19.50	19.50
Dehulled SFS	--	5.00	10.00	10.00
Dicalcium phosphate	1.25	1.25	1.25	1.25
Ground limestone	0.75	0.75	0.75	0.75
T M salt (Se)	0.35	0.35	0.35	0.35
Illini vitamin mix	0.10	0.10	0.10	0.10
Aurofac	0.20	0.20	0.20	0.20
	100.00	100.00	100.00	100.00
Calculated:[a]				
Crude protein	16.3	17.3	18.1	17.8
Lysine	.77	.82	.86	.83
Gross energy, kcal/lb	1741	1809	1877	1876
Gross energy, kcal/% lysine	2261	2206	2182	2260

[a]Values used:	C.P., %	Lysine, %	Fat, %	Gross energy, kcal/lb
Corn	8.8*	.24*	3.5*	1760**
Soybean meal	48.5*	3.0*	0.5*	1900**
Dehulled SFS**	28**	1.1**	50.5**	3125**

*Table values.

**Assay values.

Table 2. Summary of Experiment I

Diet	I	II	III	IV	
Dietary DSFS, %	0	5	10	10	
Energy/% lysine, kcal	2261	2206	2182	2260	
Average initial weight, lb[a]	20.9	20.7	21.6	20.7	Avg.
Average daily gain, lb					
Day 1 to 14	.40	.44	.48	.59	.48
Day 14 to 28	.66	.77	.70	.66	.70
Average[b]	.53[a]	.60[b]	.59[b]	.62[c]	
Average daily feed, lb					
Day 1 to 14	.97	1.08	1.08	1.10	1.06
Day 14 to 28	1.94	1.98	1.94	2.04	1.98
Average	1.45	1.53	1.51	1.57	

Table 2 continued on next page

Table 2. Summary of Experiment I, Continued

Diet	I	II	III	IV	
Dietary DSFS, %	0	5	10	10	
Energy/% lysine, kcal	2261	2206	2182	2260	
Average gain/feed					Avg.
Day 1 to 14	.420	.398	.450	.551	.456
Day 14 to 28	.348	.392	.370	.329	.360
Average[c]	.370[a]	.394[b]	.398[b]	.402[b]	
Average daily energy intake, Mcal	2.53	2.78	2.81	2.94	
Average Mcal/lb gain	3.16	3.22	3.22	3.27	

[a]Each value is an average for two pens of seven pigs each. Test was for 28 days.

[b]Values with different superscripts differ (P<.01).

[c]Values with different superscripts differ (P<.08).

Table 3. Summary of Experiment II

Diet No.	I	II	III	IV
DSFS, %	0	5	10	10
Kcal/% lysine	2261	2206	2182	2260
Average initial weight, lb[a]	44.8	44.8	45.1	45.1
Average daily gain, lb[b]	1.36	1.36	1.50	1.45
Average daily feed, lb	2.84	2.75	2.79	2.84
Average gain/feed[c]	.479	.494	.538	.511
Average daily energy intake, Mcal	4.94	4.97	5.43	5.32
Average Mcal/lb gain	3.62	3.62	3.63	3.65

[a]Each value is an average for three pens of eight pigs each, on test for 14 days.

[b]Differences among treatments P<.05.

[c]Differences among treatments P<.01.

December, 1983 1983-14

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Farrowing Management With Prostaglandin

P. A. EICHEN, B. F. BROHAMMER AND L. H. THOMPSON

Control of parturition presents many opportunities for intensive management in the farrowing facility. By inducing farrowing on certain days, more efficient use of resources could be achieved, such as effective cross-fostering to balance litter size and concentration of labor at the appropriate times. Dziuk (1979) stated that about 7% of normal piglets are stillborn and that another 15% from each litter are lost soon after birth due to weakness resulting from the parturition process. This loss is greater than all other losses from disease and management. By being able to regulate farrowing dates, it would be possible to have an assistant available to reduce this costly pig loss.

Various compounds, including oxytocin and glucocorticoids, have been used in attempts to initiate parturition, but results were not encouraging (North et al., 1973). Just prior to normal parturition, progesterone levels drop, primarily because the source of progesterone, the corpora lutea (CL), cease to function. Decreased progesterone levels in the peripheral plasma have been associated with induced parturition. Prostaglandins, a normal factor in initiation of parturition, have been found to cause destruction, or luteolysis, of the CL in laboratory species (Gutknecht et al., 1969), sheep (Thorburn and Nicol, 1971), and cows (Rowson et al., 1972). Exogenous prostaglandin $F_2\alpha$ ($PGF_2\alpha$) has been found to be effective in terminating pregnancy in pigs without any apparent serious side effects (Diehl et al., 1974; Coggins et al., 1975). Synthetic analogs of $PGF_2\alpha$ have also been used successfully in the initiation of parturition (Ash and Heap, 1973; Holtz et al., 1979; Cerne and Jochle, 1981).

The objectives of this study were to evaluate the influence of different doses and time of administration of a synthetic prostaglandin, Alfaprostol®, on the onset and duration of parturition in sows and on piglet survival.

One hundred and fifty-seven sows with known breeding dates were used in this study. The sows were assigned to one of five treatment groups just before entering the farrowing facility. Treatment groups included control sows receiving 0.0 mg of the compound and sows receiving either 0.5, 1.0, 2.0 or 3.0 mg Alfaprostol®, i.m. Injections were administered between 11:00 and 12:00 hours on day 111, 112 or 113 of gestation. All sows were allowed to farrow without assistance, in order to determine if there were any treatment effects on stillbirth rate.

Records were kept on the number of farrowings which occurred between 06:00 and 24:00 hours and the number which occurred between 24:00 and 06:00 hours. Duration of the parturition process was recorded. The interval from day 114 of

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gestation to onset of parturition was recorded for control sows. The interval from injection to onset of parturition was recorded for sows in the treatment groups. Records were kept on total, live, stillborn and mummified pigs per litter.

About 89% of all sows in this study farrowed between 6AM and midnight, thus fewer than one-fourth of the sows farrowed during the early morning hours. Parturition began within 48 hours after injection in 87.9% of all treated sows. Within the group of treated animals, average intervals from injection to farrowing ranged from 28.1 hours to 42.4 hours for the sows receiving different doses of Alfaprostol®. The interval from injection to farrowing ranged from 25 to 29 hours in other studies using $PGF_2\alpha$ or its analogs (Ash and Heap, 1973; Dieh 1974; Robertson et al., 1974). However, in other studies, much longer injection to farrowing intervals were reported (Holtz et al., 1979). The average time from noon on day 114 of gestation to farrowing was 8.7 hours for the control animals, with a range of more than four days before day 114 to more than three days after the expected farrowing date. The large range of farrowing dates of control sows exemplifies the need for regulating time of parturition, if farrowing house management is to be improved.

Table 1. Farrowing Response of Sows to Alfaprostol® Injection

Item	Alfaprostol® Treatment, mg[a]				
	Control	0.5	1.0	2.0	3.0
Number of sows	33	31	31	31	31
Time at which farrowing began					
0600-2400 hrs	26	28	31	27	27
2400-0600 hrs	7	3	0	4	4
Treatment to onset of parturition, hrs	8.7±45.9[b]	42.4±46.4	30.6±20.8	28.1±18.0	30.4±27.8
Farrowing duration, hrs	3.2± 1.0	3.4± 1.2	3.6± 2.7	3.8± 1.7	4.0± 2.6
Gestation length, d	114.4± 1.9	113.4± 2.1	112.9± 1.3	112.7± 1.1	112.9± 1.3

[a]Injected on day 111, 112 or 113 of gestation.

[b]Noon on day 114 of gestation to farrowing, hrs.

Seventy-two percent of the treated sows started farrowing between 20 and 48 hours after injection, regardless of the day of gestation on which Alfaprostol® was given. Of the treated animals 12.1% farrowed more than 48 hours after receiving an injection. Twenty-one point two percent of the control sows farrowed more than two days after day 114 of gestation.

The duration of the farrowing process was very similar for all groups, averaging between 3.2 and 4.0 hours. No treatment differences were detected for this time period. There was no significant effect of day of injection, whether 111, 112 or 113, on time from injection to onset of parturition or on stillbirth rate. Thus, sows can be induced to farrow on day 112 or later with no ill effects.

The lack of response in some animals could be due to a variety of genetic and environmental factors. Results from studies using animals of different genetic makeup have shown different responses (Dieh
effect may be indicated, as well.

Table 2. Litter Size and Stillbirth Rate as Influenced by Alfaprostol® Treatment

Item	Alfaprostol®, mg[a] Control	0.5	1.0	2.0	3.0
Number of sows	33	31	31	31	31
Total pigs born per litter[b]	11.1	10.7	10.8	10.5	10.6
Live born pigs per litter	10.0	9.9	9.8	9.4	9.8
Stillborn pigs per litter	1.1	0.8	1.0	1.1	0.8

[a]Injected on day 111, 112 or 113 of gestation.

[b]Excluding mummies.

Total number of piglets born, number of piglets born live and number of stillborn piglets per litter were similar in all groups. Cerne and Jochle (1981) indicated that the induction of parturition reduced stillbirth rate. However, these data and that from other studies do not support their findings.

Some dystocia and other problems were observed in all groups of sows, with no relationship between problems and gestation length. There were no significant differences in sows for the occurrence of problems, such as retained placentas, agalactia or other problems between control animals and treated animals or between treatments.

The 1.0, 2.0 and 3.0 mg doses of Alfaprostol® all gave good control over time of treatment to parturition and gestation length. The farrowing responses to the various treatment levels were not significantly different; however, the most efficient response for time of treatment to onset of parturition was observed for the 2.0 mg dose. This dose was the most effective in controlling gestation length, as well, indicating that it would be the most efficient dose to use in regulation of farrowing. There was a slight, but insignificant, increase in the number of stillborn pigs per litter over the other treatments, with the 2.0 mg dose. Cerne and Jochle (1981) found the 2.0 mg dose of Alfaprostol® to be the most favorable for parturition regulation.

As a result of this study, it appears that about 88% of treated sows would farrow within 48 hours after receiving Alfaprostol®. This could be very useful to the swine industry. Inducing farrowing with Alfaprostol® would cause farrowing to occur in a short, predictable time period, with no adverse effects on the sow or piglets. If all farrowings could be timed to occur between 06:00 and 24:00 hours on one day, this would constitute a practical and very productive work day. This is in contrast to the unpredictable farrowing patterns of sows in which parturition has not been induced, where farrowing can occur at any time over a period of a week or more. With the use of an induced farrowing system, the resultant increase in efficiency of facilities utilization and the value of pigs saved would make it economically feasible to have an attendant on duty for a shorter, predetermined farrowing period.

Opportunities for improved farrowing house management would arise from a controlled farrowing program. More uniform pigs would be produced, since all pigs would be similar in age and cross-fostering could be employed to reduce within and between litter variation. Increased pig uniformity would promote synchronized pig processing, weaning and mating of sow groups, making the use of an all-in, all-out concept more feasible. Weekend farrowing could be eliminated by the use of controlled farrowing. A program allowing natural farrowing on Monday, Tuesday and Wednesday, with injection of all sows on day 111 or more of gestation on Thursday could be employed. By using a system of injecting sows on Monday and Thursday, farrowing could be limited to only two days a week.

Prostaglandins can be used to induce parturition on day 112 of gestation and later, but pig survival is very poor if induction occurs before day 111. In the industry, this system could be used to induce farrowing on day 112 or 113 of gestation. Some sows will farrow naturally earlier than day 114, at an unpredictable time. By the use of induced parturition on day 112 or 113, the farrowing times of these sows could be predicted and an attendant available to give any needed aid to the sow and piglets.

An induced farrowing program is not applicable to all management systems. The exact breeding date must be known, as injection of prostaglandin before day 110 or 111 results in poor piglet survival. Very close management would be required for such a program. Sows must be bred as close to the same time as possible in order to make the most efficient use of such a program. Since records of exact breeding dates are not usually known for pen or pasture mating systems, the induction of farrowing with prostaglandin cannot be used in these situations.

ACKNOWLEDGEMENTS

Alfaprostol® (RO 22-9000). This study was supported in part by a grant from Hoffmann-LaRoche, Nutley, New Jersey.

Thanks go to Tom Park, Bob Gilbert and all the staff at the Moorman Animal Breeding Research Farm for their cooperation and assistance in this study.

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Energetics of Growth in Pigs

R. W. JONES AND R. A. EASTER

[NOTE: The following manuscript was prepared by R. W. Jones for discussion in a graduate seminar in Animal Science. The concepts are fundamental and particularly relevant as the swine industry faces the present challenge of producing lean pork and anticipates the development of metabolic regulators that will beneficially alter these basic processes. Thus, this manuscript is included in the 1983 Swine Research Report as "food for thought".]

INTRODUCTION

Growth is a fascinating subject by virtue of its ubiquitousness. Those with increasing waistlines may decide it is a broadening subject, but earlier in our lives growth dealt with longitude as well as latitude.

What is growth, you may wonder. Many of us, however, do nothing more than wonder why we have grown the way we have. If I asked the question, you may respond by stating when a thing grows, it gets bigger. As scientists are fond of saying, it is not that simple. Physically, we are not simply big infants, nor is a mature pig just an overgrown piglet. The body structure, proportions and functions develop and differentiate as an individual grows.

In an essay published 55 years ago, Samuel Brody very skillfully described how growth and senescence simultaneously take place in man (Brody, 1928). He quoted an even more eloquent writer than himself to illustrate the differentiation in man. Shakespeare (from As You Like It) distinguished seven stages of growth in man:

> At first the Infant,
> Mewling, and puking in the Nurses armes:
> Then, the whining Schoole-boy with his Satchell
> And shining morning face, creeping like snaile
> Unwillingly to schoole. And then the Lover,
> Sighing like Furnace, with a wofull ballad
> Made to his Mistresse eye-brow. Then a Soldier
> Full of strange oaths, and bearded like the Pard,
> Jelous in honor, sodaine and quicke in quarrelle,
> Seeking the bubble Reputation
> Even in the Canons mouth: And then, the Justice
> In fair round belly with good Capin lin'd,
> With eyes severe, and beard of formall cut,
> Full of wise sawes, and moderne instances,
> And so he plays his part. The sixt age shifts

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Into the leane and slipper'd Pantaloone,
With spectacles on nose, and pouch on side,
His youthful hose well sau'd, a world too wide,
For his shrunke shanke, and his bigge manly voice
Turning againe toward childish treble pipes,
And whistles in his sound. Last scene of all,
That ends this strange eventful historie,
Is second childishnesse, and mere oblivion,
Sans teeth, sans eyes, sans taste, sans everything.

Having this set stage, several questions logically arise. First, if growth is finite, there should be a point when the maximum rate of growth is achieved and proceeding past that point results in decreasing marginal returns to the input.

However, to identify this point, we must return to the question of what is growth: do all parts of the body grow at the same rate? Julian Huxley investigated the problems of relative growth using the Fiddler Crab as his model in his classical studies of differential growth (Huxley, 1932). Huxley compared the claw weight to the total bodyweight of the crab. He noted that the proportion of any part to the whole was more a function of the weight of the whole than of the age of the animal. His regressions resulted in the application of the allometric equation to growth studies:

$Y = a + X^b$ or $\log Y = a + b \log X$ (where Y = weight of the part, X = weight of the whole, a and b = constants)

Huxley was the first to promote the use of this equation. It is unique in that it recognizes the constant ratio of part to total weight, which is represented by the coefficient b, Huxley's "growth-coefficient".

One of Huxley's contemporaries, Sir John Hammond, did not feel that Huxley's equations fit domestic livestock, since animals fed at different rates had vastly different body compositions. Hammond and his school at Cambridge commenced now classical studies on how nutrition affects the composition of pig carcasses at slaughter. These results are published by McMeekan (1940a,b,c, 1941), who with Sir John Hammond and others (Pálsson, 1955), postulated that growth of an organ or tissue occurs in phases or waves. Tissues which were "early maturing" exhibited their maximum growth intensity in early life, while the "late-maturing" tissues developed in waves over time.

However, McMeekan's results proposed several exceptions to their hypothesis and further work in this area by the Cambridge group successfully divided the school on the theories of growth. Upon re-analysis of McMeekan's data, the group at the Rowett Research Institute found that fat was the major variable and if "removed" from the total bodyweight of the animal, the nutritional regime did not appear to alter the proportions of tissues to the fat-free bodyweight of McMeekan's pigs (Elsley et al., 1964). Therefore, if fat is not considered as a component of total bodyweight, Huxley's allometric equation appears valid, and, in fact, is used quite widely in studies of growth modeling today.

In a review by Fowler (Fowler, 1980) of the progression of growth modeling theories, he attempts to summarize the seemingly complex growth response to nutrition. Assuming a background of comparatively stable nutrition, he makes two major simplifications:

a) The major differences in body proportions at the same liveweight produced by changes of nutrition are the consequences of differences in the ratio of lean-to-fatty tissues.

b) The proportions of parts of the lean body to the whole of the lean body, and of the parts of the fatty tissue to the total fat, tend to be determined by the absolute total weights of lean and fat considered in the same multiple regression equation.

These assumptions, which appear to be very simplistic, are in fact essential to many growth studies and theories.

We are now finally able to provide a partial response to the ubiquitous query of what is growth in an animal -- a pig, to be specific. It is fat and tissues-not-fat. More importantly, however, of tissues-not-fat, we are concerned with lean, high-quality meat.

At this point, switching from biology to economics is not only logical, but necessary. It should be obvious that "it is of no particular merit to produce twice as much of a high-value part of the carcass if it costs four times as much to do it", to quote Dr. Fowler (Fowler, 1980). Hence, not only should the nutritionist and producer be concerned with the energetics of producing growth, but also the efficiency of growth, especially of lean meat.

Energy Costs of Growth

When describing growth in pigs, we are mainly concerned with fat and protein deposition. These are of economical importance. The energy costs of growth can be approached through two avenues: first, by a factorial or theoretical method, and second, by actual experimentation. I shall employ both methods and will discuss the significance of the results.

Dr. Jan Kielanowski, from the Institute of Animal Physiology and Nutrition in Jablona, Poland, and his group there were in the forefront of the discussion of this topic when it began not quite two decades ago. Kielanowski sets four assumptions as the basis for factorially deriving the costs of protein and fat deposition (Kielanowski, 1966). They are:

1. The only important determinants of the energy balance are the expenditures of energy in maintenance, in protein deposition and in fat deposition, all others being negligibly small.

2. The net energy cost of fat and protein deposition remains approximately constant in pigs of all ages and liveweights, whatever the level of nutrition.

3. The average daily maintenance requirements of pigs growing from one bodyweight to another and kept under similar environmental conditions are constant, irrespective of their daily gains.

4. The ratio of non-fat components to protein in the gains of pigs over a similar liveweight range is virtually constant.

From these assumptions, Kielanowski mathematically deduced the expression of feed conversion ratio as a function of average daily protein deposition, the average daily maintenance requirements and the average daily intake of energy to be made. He also demonstrated the dependence of the feed conversion ratio on each of these three factors.

If one follows the natural progression of relationships between metabolizable energy (ME) intake and the energy retained, it can be seen where Kielanowski made his jump, as it were, into dividing growth into its important components. The simplest factorial estimate is described by the linear equation:

$$ME = a + \left(\frac{1}{k_w}\right) ER$$

where ME is the intake of ME, ER represents the total energy retained, and k_w and a are constants with k_w representing the partial efficiency of utilization of metabolizable energy for retention and a the intercept which provides an estimate of the ME required for maintenance (ME_m). Modification of this equation allows for the separation of ME used for maintenance and that for production:

$$ME = \left(\frac{1}{k_m}\right) FM + \left(\frac{1}{k_w}\right) ER$$

where ME = intake of ME (MJ/d); FM = fasting metabolism (MJ/d); k_m = efficiency of utilization of ME for maintenance; k_w = efficiency of utilization of ME for energy retention above maintenance (for production); and ER = retention of energy above maintenance (MJ/d).

Neither of these equations takes into account the possible, and as we know, actual variation in the proportion of protein and fat retention in the gain. Kielanowski first proposed that multiple regression analysis could be used to separate the energy cost of protein and lipid accretion. Modified slightly from his original equation (Kielanowski, 1965), it can be written as:

$$ME = ME_m + \left(\frac{1}{k_p}\right) P + \left(\frac{1}{R_f}\right) F$$

where ME = metabolizable energy (MJ/d); ME_m = metabolizable energy for maintenance (MJ/d); P = energy retained as protein (MJ/d); F = energy retained as fat (MJ/d); k_p = efficiency of utilization of energy for protein accretion; k_f = efficiency of utilization of energy for fat accretion.

This equation is used to predict growth in many computer models. The progression of growth equations seems intuitively obvious, but until recently, unbiased estimates of the three crucial parameters of maintenance per unit of metabolic bodyweight and the energy costs of protein and lipid deposition have not been available.

The theoretical energy costs of protein deposition can be estimated directly and indirectly. The direct method utilizes knowledge of the biochemistry of protein synthesis and turnover and because of the incomplete understanding of these processes, this method often fails. The indirect method is actually a method by difference: one determines the cost of maintenance and the costs of all processes other than protein synthesis and subtracts them from total energy needs. This energy balance method, too, is saddled with the burden of many estimates and assumptions. Typically, the indirect estimates are considerably lower than the maximum values estimated directly.

Van Es recently reviewed the estimation of the cost of protein deposition using both methods (Van Es, 1979). The indirect calculations are very detailed, so I will present only a simplified summary of his direct calculations of the cost of protein synthesis.

To synthesize one mole of protein (115 grams, 645 kcal) from one mole of amino acids, peptide bonds must be formed and Van Es estimated the cost of peptide formation to be five moles of ATP, the body's energy store. The energy cost of forming one mole of ATP varies with the substrate used (carbohydrate, fat, protein), but is approximately 18 kcal/mole. Therefore, to synthesize 100 grams of protein, the cost is 77 to 94 kcal of ME [(5 mole ATP/115 grams protein)(100 g protein)(18 to 22 kcal/mole ATP)]. The theoretical efficiency of protein synthesis is therefore (575 kcal ME x 100 grams protein) ÷ (77 to 94 kcal ME + 575 kcal ME), which is 86 to 88% efficient.

However, the deposition of protein is not synonomous with protein synthesis but is the net result of synthesis and degradation. Degradation of protein does not immediately yield ATP; thus, the cost of the degradation must be accounted for. The cost of protein renewal, however, can be charged to the animal's cost of maintenance since it is not connected directly with protein deposition itself and exists as long as the protein exists. There is some indication, however, that protein turnover increases with increasing rate of protein deposition. If one assumes that the cost of maintaining a 100 g protein deposition is approximately 3% per day, and a deposition of 200 g per day increases the renewal cost to 8% per day, then the theoretical efficiency for protein deposition can be calculated to fall to 61-65% (Van Es, 1979).

It must be stated that our knowledge of protein turnover rates and their costs and the cost of peptide formation is insufficient at best. Therefore, these estimates are not precise quantitative estimates of the cost of protein deposition.

The indirect methods Van Es described are no less conclusive, but are substantially lower than the direct estimates and showed much variation, 40 to 60%. In attempting to explain the differences, Van Es questioned three assumptions:

1. That of equal maintenance requirement at the same bodyweight at different levels of feeding.

2. That the energy costs of protein deposition may differ between strains of the same species.

3. That 5 mol of ATP is not required for 1 mol of protein synthesis.

The theoretical conversion of ME to body fat is very efficient. The maximal k_f value agreed upon by several different groups has been calculated to be 0.99 from dietary lipid, 0.85 from dietary carbohydrate, and 0.69 from dietary protein.

As I mentioned earlier, Kielanowski pioneered energy metabolism in a way. He worked with very young pigs and used the indirect calorimetry method of determining efficiencies of growth; that is, he used heat production and comparative slaughter techniques to base his arguments.

These arguments and the resulting determinants of partial efficiency of energy utilization have come under some criticism because of the estimation of metabolizable energy used for maintenance. It has been shown that at energy equilibrium, where there is no net gain or loss of total energy, fat may be lost and protein accreted. Close and Mount (1978) estimated that between 4 and 7 g of nitrogen could be retained daily at energy equilibrium in pigs weighing 35 to 45 kg. Likewise, workers at the Rowett Institute (Fuller et al., 1976) found that pigs of 30 to 60 kg liveweight could accrete 3 to 5 g of nitrogen per day at "maintenance".

The Agricultural Research Council (ARC) recently summarized what they considered to be the most reliable estimates of the efficiency of ME energy (ARC, 1981). The estimates are given in Table 1.

Table 1. Daily Energy Utilization: Estimates of the Efficiency of Utilization of ME for Protein (k_p) and Fat (k_f) Synthesis. Estimates Determined Within the Zone of Thermal Neutrality Either by Calorimetry or by Comparative Slaughter

	Live wt., kg.	k_p	k_f
1.	8-15	0.80	0.70
2.	15-45	0.58	0.86
3.	23-42	0.58	0.70
4.	20-50	0.63	0.70
5.	20-90	0.35	0.73
6.	20-90	0.55	0.62
7.	30-110	0.52	0.70
8.	30-90	0.53	0.69
9.	40-110	0.53	0.92
10.	116-200	0.56	0.93
11.	114-154	0.40	0.96

The preferred estimate of k_p is taken from data obtained from pigs of 90 kg or below listed in Table 1 and is assumed for pigs below 90 kg to be 0.54. This in turn gives the cost of depositing 1 kg of protein as 10.5 Mcal ME and the cost of retaining 1 Mcal energy in the form of protein as 1.85 Mcal ME.

Similarly, the preferred value of k_f for pigs is taken as 0.74. This gives the cost of depositing 1 kg of fat as 12.74 Mcal ME and the cost of retaining 1 Mcal energy as fat as 1.35 Mcal ME.

These preferred estimates of energy utilization efficiency from the ARC agree well with the contemporary-classic estimates reported by Pullar and Webster (1977). These researchers at the Rowett Institute designed an experiment with lean and obese Zucker rats such that the assumptions of energy requirements for maintenance would be eliminated.

Pullar and Webster fit their data to an equation similar to Kielanowski's,

$$ME = A + b\ RE_p + cRE_f,$$

where ME is ME intake and RE_p and RE_f are energy retained as protein and fat, respectively, all values expressed as kcal/day. Therefore, b and c become the ME required to deposit 1 kcal of protein and fat, respectively, and the solution for A is the maintenance requirement. They found the following solution:

$$ME = A + 2.25\ RE_p + 1.36\ RE_f.$$

The inverse of b and c will yield the partial energetic efficiency coefficients for depositing protein and fat. Therefore, Pullar and Webster found k_p to equal 0.44 and k_f to equal 0.74, which agree fairly well with the ARC's preferred estimates of protein and fat deposition efficiencies.

These numbers and concepts are fine for those who serve the scientific community as they increase our knowledge of the biochemistry of growth. Unless these ideas and results can be formed into a model that is useful to the nutritionist and producer alike, then they serve no purpose. There are, however, tremendous pitfalls and dangers in oversimplifying growth models. The best one can do at this time and place in our knowledge is to take a stance while remaining aware of the possible drawbacks.

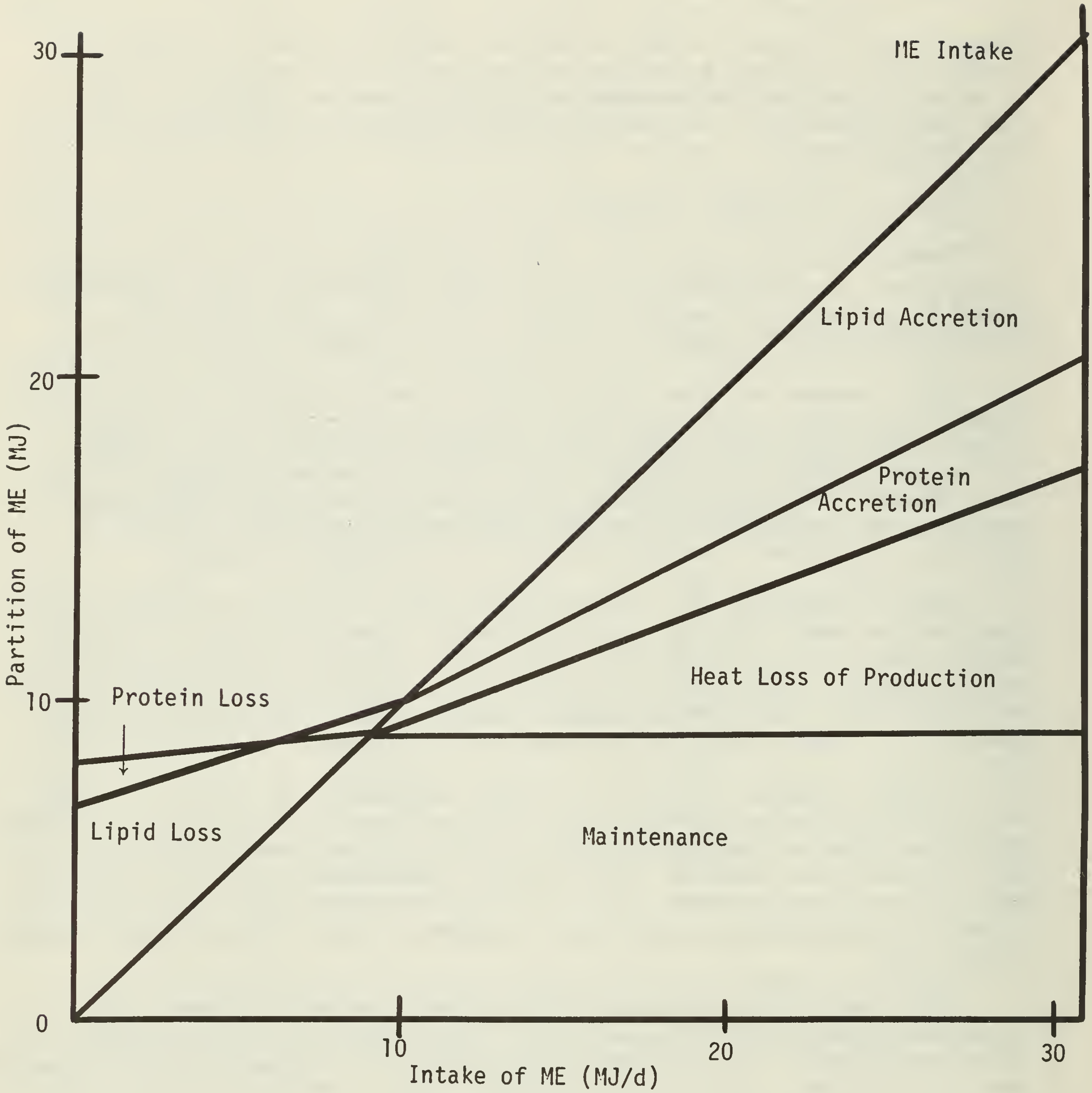
This is precisely what Vernon Fowler did at the Rowett Institute. He proposed the model relating the partitioning of ME in the body to the ME intake given in Figure 1 (Fowler, 1980). Dr. Fowler limits his discussions to pigs growing from 30 kg to 90 kg and uses a 60-kg pig as his choice. He assumes that within these weights, changes in the relationship between tissues are linear, which is an assumption that appears approximately true.

A major problem in Fowler's factorial approach is to predict the rate of nitrogen retention in relation to daily ME intakes at different liveweights. It is the slope of the protein accretion line that has been disputed in the literature and over the coffee table. Some contend that it is essentially linear, while others favor a curvilinear slope, while still others argue for a plateauing of the linear response as daily intake of ME increases (ARC, 1981).

The slope of the line itself is dependent upon many factors, among them being genotype, sex, age and diet. These are basically specified in Fowler's model. The biological truth may lie in between all three possibilities for the efficiency of protein disposition. This is easily related to the practical situation where one may note that young pigs of high potential on a good diet may respond to ME intake in a linear fashion, whereas for older and heavier pigs, castrates and poor genotypes, the response of nitrogen retention to increases in feed intake may fall to zero at high intakes.

CONCLUSION

Those scientists in the 1920's who first tackled the problems of describing growth were more philosophical about their approaches than those of today, and for obvious reasons. Nevertheless, today's scientists are still faced with rather cogitative problems in describing growth, especially when the



Assumed values: k_p = 0.52
k_f = 0.73
ME_m = 9.56 MJ ME/day

From Fowler (1980)

Figure 1. Partition of ME at Different Rates of Intake for a Pig of 60 kg Liveweight

assumptions used from theories may be in error or inadequate. One example is, of course, the definition of the maintenance energy requirement. Another is the assumption of overall efficiency of pork production. If the efficiency of protein deposition does in fact fall after a certain weight, has the marginal rate of return to input, input being metabolizable energy intake, reached a maximum? If it has reached a maximum, should it not also be more efficient to slaughter pork at this weight?

With the continued refinement of technology, the quantitative biochemistry of growth processes will be better understood. For example, protein turnover needs to be more completely understood. There are plenty of unanswered questions concerning very young pigs and pigs above common slaughter weights that will intrigue and stimulate researchers; questions concerning limitations to growth and protein deposition, limitations in fat deposition, and can man manipulate these processes?

Traveling from futuristic thoughts to those of 60 years ago, William Robbins (Robbins, 1928) concluded an introductory chapter on growth with a philosophical note, which I shall do likewise:

The process of growth is a wonderful and remarkable one, even in the meanest and most humble of living creatures. No matter how small we are, or how poorly our features are collected on our countenances, we should never be dissatisfied. We should never regret that we have not attained the stature of a Hercules or the features and form of a Venus. We should feel astonished and thankful that we ever grew at all and that our features are recognizable as those of the human race.

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December, 1983 University of Illinois at Urbana-Champaign 1983-16
College of Agriculture Agricultural Experiment Station
Cooperative Extension Service Department of Animal Science

Behavior of the Mated Gilt in a Turn-Around Gestation Crate

J. M. McFARLANE AND S. E. CURTIS

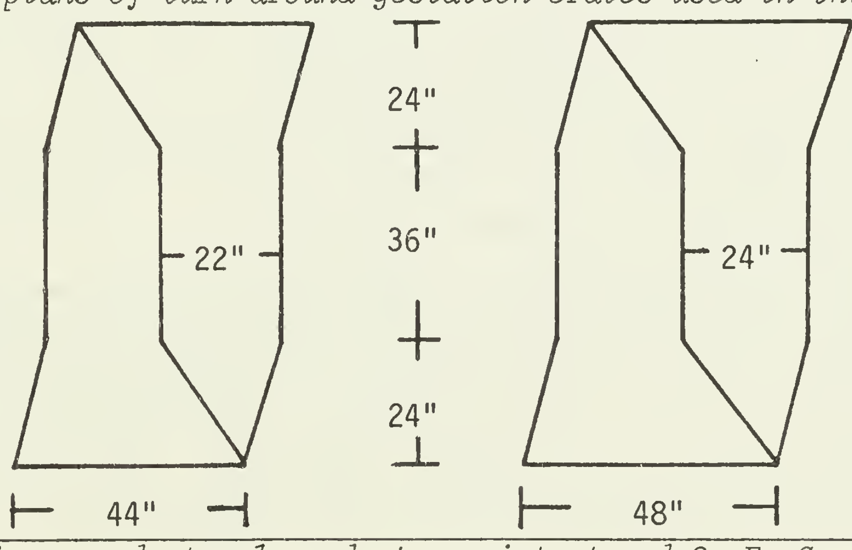
Gestation crates of various dimensions and materials are widely used in the pork industry today. They make it possible to feed pregnant gilts and sows individually, to keep them separated and thus reduce injuries due to fighting, to conserve space and cold-weather fuel, and to accommodate liquid-waste handling. But gestation crates do limit the animals' movement. Sows can walk no more than a step or two in most crates, and they are unable to turn around. This last point is of interest because some people have suggested that turning around might be a behavioral need of swine. If it is, then deprivation in this regard might have negative effects on the health, performance, and overall well-being of pregnant gilts and sows.

We reported last year that the behavior and performance of mated gilts through day 28 postmating were roughly the same in a turn-around crate of our design as in two different group-pen and two different standard-crate arrangements (McFarlane et al., 1982). The purpose of the experiment reported now was to explore in finer detail the behavior of mated gilts in turn-around crates in a first attempt to learn whether the opportunity to turn around is a behavioral need of this animal.

EXPERIMENTAL PROCEDURES

Two pairs of turn-around crates were used. One pair measured 22" each across the center section, while those in the other were each 24" wide (Figure 1). Each crate was 7' long and covered the same floor area as a standard gestation crate nominally 22" X 7' or 24" X 7', respectively. The space at the wide end of a crate permitted the gilt to turn around at will. The floor under the crates

Figure 1. Floor plans of turn-around gestation crates used in this study.



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was galvanized woven wire. Surrounding each pair of crates was black plastic film, 8' high and 5.6' away from front and rear and 2.5' away from the sides of each pair. A gilt's view of this blind was the same regardless of the direction she faced.

Sixteen mated Landrace-Hampshire gilts were studied. In each of four trials, two gilts were held in the 22"-wide crates and two in the 24"-wide. Body weights of all gilts ranged from 245 to 310 lb, averaging 290 lb, when trials started. Body length from head crown to tail base ranged from 52" to 58", averaging 56".

Each gilt was fed 5 lb of a standard corn-soy gestation diet once daily. Crates were washed thoroughly at each feeding time to minimize chances of the gilts' developing preferred dunging patterns on the basis of fecal accumulation. Air temperature was kept at 70°F ± 2 F°.

All gilts were mated twice by natural or artificial service. Gilts within a pair received second services within 48 hr of each other, and were placed in turn-around crates at the same time, no later than 24 hr after the last service of the later-mated gilt of the pair.

Gilts were given a four-day adjustment period to learn how to turn around. During this time, the feeder was located at the narrow end of the crate, the nipple waterer at the wide.

After the adjustment period, feeder and waterer locations were arranged in accordance with one of four permutations: (1) both feeder and waterer at wide end; (2) both feeder and waterer at narrow end; (3) feeder at wide end, waterer at narrow; and (4) feeder at narrow end, waterer at wide. The four permutations were imposed for 6 days each in a sequence which varied randomly over the four trials.

The behavior of all gilts was recorded continuously by time-lapse video-recording equipment during the last 3 days of each permutation period. Behaviors quantified were: turning frequency, percentage of time facing wide end of crate, and percentage of time a pair of gilts were oriented head-by-head. Data were analyzed to determine whether turning or orientation were affected by crate width, feeder/waterer locations, same end versus opposite ends for feeder and waterer, or feeder or waterer location independent of each other.

RESULTS AND DISCUSSION

The gilts did learn, usually by themselves, to turn around in the special crates in which they were held in this experiment. The overall average frequency of turning around approached 12 times per day (Table 1).

Feeder/waterer permutation did not significantly affect the number of turns a gilt made during a 3-day observation period. On the other hand, gilts in 22"-wide crates turned less often than did those in 24"-wide crates (Table 1) ($P<.05$). It is likely that they found it more difficult and uncomfortable, although still possible, to turn around in the narrower crates. Turning frequency was not influenced significantly by any other independent variable. These results suggest that the gilts were motivated to turn around by one or more factor(s) other than, or at least in addition to, merely the locations of feed and water.

Table 1. Summary of data from the experiment

Comparison	Turning frequency (no./3 days)[a]	% of time facing wide[a]	% of time head/head[a]
Feed at wide, water at wide	30 ± 5.2	61 ± 9.6	51 ± 14.1
Feed at narrow, water at narrow	35 ± 6.4	43 ± 8.3	62 ± 9.0
Feed at wide, water at narrow	38 ± 6.8	63 ± 11.1	50 ± 14.1
Feed at narrow, water at wide	40 ± 5.8	52 ± 8.2	61 ± 8.3
Feed at wide end	34 ± 3.9	62 ± 7.1[d]	51 ± 9.4
Feed at narrow end	38 ± 4.3	48 ± 5.8[e]	61 ± 5.9
Water at wide end	35 ± 3.9	57 ± 6.2	56 ± 7.8
Water at narrow end	37 ± 4.3	52 ± 7.0	57 ± 7.9
Feed and water at same end	33 ± 4.0	52 ± 6.5	56 ± 8.2
Feed and water at opposite ends	39 ± 4.1	57 ± 6.6	56 ± 7.4
22"-wide crate	29 ± 4.7[b]	63 ± 6.8	57 ± 9.6
24"-wide crate	41 ± 3.3[c]	49 ± 6.1	55 ± 6.4

[a]Values are treatment means ± SEM based on 16 mated gilts each subjected to all four feeder/waterer locations permutations, 8 in 22"-wide crates and 8 in 24"-wide.

[bc]Values in same column with different superscripts differ ($P<.05$).

[de]Values in same column with different superscripts differ ($P<.07$).

Neither feeder/waterer location nor crate width had any significant effect on direction faced (wide or narrow end of crate). And neither did relative locations of feeder and waterer nor location of feeder or waterer independent of the other affect this trait. But the gilts did spend more time facing the wide end of the crate when the feeder was located in the wide end, regardless of where the waterer was located.

Differences in the gilts' orientation to each other--head-by-head or head-by-tail--as influenced by the independent variables were mostly small and in no case statistically significant. There was a tendency for the two gilts in a pair to spend more time lying head-by-head, but neither was this tendency significant.

In recapitulation:

(1) Width of turn-around crate significantly affected the gilts' turning frequency. The greater difficulty presumably associated with turning around in a 22"-wide crate as opposed to a 24"-wide crate appears to have been a deterrent to turning behavior.

(2) When the feeder was in the wide end of the crate, the gilt tended to face that end more than the narrow.

(3) There was no effect of feeder location alone or waterer location alone on any quantified behaviors.

(4) The gilts showed no significant preference to lie head-by-head as opposed to head-by-tail.

CONCLUSIONS

Gilts in turn-around crates did turn around a considerable number of times--almost 12 times on average--each day. This turning activity did not appear to be entirely motivated by the need or the desire to face the feeder or waterer, the wide or narrow end of the crate, or the head or tail of the neighboring gilt. Many turns seemed to be made simply in order to face in the opposite direction. This conclusion is supported by the fact that gilts with both feed and water at the same end of the crate turned around just as often as did those with feed and water at opposite ends.

Turns often appear to have been made in relation to no obvious external stimulus. It has recently been suggested that, when a behavior occurs in a fashion seemingly unrelated to environmental stimuli, it probably is being driven largely by internal factors and might be a needed behavior (Hughes, 1980). In the case of gilts in turn-around crates, when feeder and waterer were located at opposite ends of a crate, it is clear that a gilt was always facing one or the other and that sooner or later she must have turned around to gain access to the other one of these fundamental biological needs. But gilts turned around just as often when both feed and water were in the same end. This means that the opportunity to turn around might be a behavioral need in the pregnant gilt.

In order to establish turning around as an essential behavioral need requiring accommodation by the environment, according to Hughes's approach, it would need to be proven that deprivation of pregnant gilts in this respect leads to distressful frustration; that is, that the pregnant gilt cannot in some way cope adequately with the absence of the opportunity to turn around so as to preserve a satisfactory sense of overall well-being. The fact that narrowing the crate from 24" wide to 22" reduced the frequency of turning around by over 25% suggests that, if turning around is a behavioral need at all, it is not a strong need.

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December, 1983 University of Illinois at Urbana-Champaign 1983-17
College of Agriculture Agricultural Experiment Station
Cooperative Extension Service Department of Animal Science

Toy Preferences in Young Pigs

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Some pork producers have placed bowling balls, chains, and various other purported toys in swine nursery and finishing pens in attempts to reduce vicious behavior and boredom. Practical experience suggests that the effects of these toys on the pigs have been variable.

Casual observations indicated that 5- to 14-week-old pigs would stop playing with an object unless it was changed often, and that they would play with some objects longer than others. A strip of cotton cloth tied to a fence was chewed for approximately a week, whereas a plastic milk crate was ignored after two or three hours and a newspaper was the focus of five minutes of intense activity but was ignored after it had been torn up. Also, once an object had become contaminated with manure, the pigs tended to avoid it. Two pigs were often observed fighting with each other to gain access to a toy. They fought over a toy in the same manner as they would fight to gain access to a position at the feeder.

The purposes of the study reported here were (a) to determine the pig's preferences for different kinds of toys and (b) to determine if these preferences change as time passes. This knowledge would be valuable to producers as it would enable them to use the most effective objects as toys.

Two 10-day toy-preference trials have been conducted so far. Eight head of 9-week-old pigs were used in each trial. The pigs were housed in pairs in 4' X 4' nursery pens with plastic-coated expanded-metal floors. After a 3-day adjustment period, the trial was started.

Three toys were offered to the pigs. They were suspended from strings which were attached to a wooden bar. The toys were: a brass-plated chain with .5" welded links, a 2"-wide black cotton cloth strip, and a piece of black rubber hose with an inside diameter of .25" and an outside diameter of .4". These three objects were chosen because they provided different hanging characteristics and different textures for mouthing and chewing. Two wooden bars with each of the three objects were offered to the two pigs in each pen for 15 min each day. Each pig was observed for 5 min within this period, in random order across days. The following behaviors were recorded: number of times a pig touched a toy, number of times a pig bit or chewed a toy, duration of touching a toy, and duration of biting or chewing a toy.

Early results indicate that the pigs indeed have clear preferences among the choices presented, that these preferences seem to change over time, and that larger pigs' preferences might differ from smaller ones'.

Preferences might be related in part to the pig's ability to grab an object

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with its mouth. Some of the smaller pigs had difficulty grabbing the hose because it tended to swing away from them. The cloth was difficult to grab until a weight was tied onto the end of it. Pigs chewed on any object they could easily grab with the mouth. Preferences might have been related to the objects' textural differences, too.

More experiments will have to be conducted to learn more about the pig's toy preferences.

December, 1983 University of Illinois at Urbana-Champaign 1983-18
College of Agriculture Agricultural Experiment Station
Cooperative Extension Service Department of Animal Science

Objective Measurement of Effects of Environmental Complexity on Young Pigs

T. GRANDIN, S. E. CURTIS AND W. T. GREENOUGH

Some people are concerned that swine might not be receiving an adequate amount of environmental stimulation in some modern systems of pork production. The overall purpose of the study reported here is to develop objective ways of measuring effects of environmental complexity on behavior and central nervous system development in swine. Until such methods are available, questions as to whether swine experience distress due to understimulation in certain production settings cannot be answered in scientific fashion.

Twelve weanling Hampshire-sired crossbred pigs aged 5 weeks at the start were held for 9 weeks in each of two different environments. The supposedly simple experience consisted of two pigs in each of six 4' X 4' nursery pens with plastic-coated expanded-metal floors. Light intensity and temperature in the room were kept more or less constant at all times. These pigs were not handled except for routine feeding and pen-cleaning every third day.

The supposedly complex experience consisted of 12 pigs together in an outdoor pen with free access to an adjoining house bedded with straw. These pigs were handled and played with by the experimenter for at least 15 min, and up to 30 min, each day. They were also provided various objects with which to play: plastic milk crate, garbage can, ropes, twine, newspapers, dirt, stones, cloth strips, and beverage cans, among other items. Some were changed daily.

Differences between the two environments were deliberately made extreme in this first experiment. This was the first step in trying to establish the range of effects these rearing environments can have on the parameters measured in the pigs.

BEHAVIORAL TESTS

At the end of the 9-week existence in one of the two environments, each pig was tested for time to approach a strange man and a novel object, respectively. Each pig was placed individually in a small novel pen in which there was either the strange man or the novel object (a new red feeding trough standing on end). The order of presentation of man or trough was random across pigs.

There were differences in behavior between pigs in the two groups. Pigs from the complex environment approached both the novel object and the strange man more quickly than did their counterparts from the simple environment: pigs from complex environment, approach man--59.5 sec, and approach object--49.8 sec; pigs from simple environment, approach man--100.3 sec, and approach object--83.5 sec.

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There also appeared to be effects of litter on the pigs' behavior. One pig from the complex environment became extremely excited during the approach tests and vocalized loudly. She and her littermates were much slower to approach the strange man, regardless of rearing environment (125.9 sec versus 60.9 sec for all other pigs from both environments).

Casual observations in practical farm environments suggested that pigs raised outdoors are usually more cautious and have larger flight zones than those raised inside a house, in closer proximity to humans. When pigs from the complex environment were first placed outdoors, they had larger flight zones than did those from the simple environment. For several weeks, they usually would run away when approached by the experimenter. They were gradually tamed by the experimenter, who sat or stood quietly in the pen and allowed the pigs to investigate coveralls and boots. It is likely that the variable that affected the results of the approach-man test was amount of previous contact with humans.

The most dominant pig in the complex-environment group was the last individual which would stand to be petted or handled by the experimenter. This gilt would run up to and bite the experimenter while other pigs were being petted. Slapping her on the rear end or yelling at her did not stop her biting. It was thought that the dominant pig's behavior might be changed if the experimenter asserted dominance over her. Pigs demonstrate dominance over one another by biting and pushing at the neck and shoulders. To simulate another pig's biting and pushing, the experimenter shoved a board against the dominant gilt's neck and pushed her up against a fence. Shortly after this incident, she started to allow the experimenter to pet her and most of her biting stopped. But she remained dominant over all other pigs in the pen.

CENTRAL NERVOUS SYSTEM MEASUREMENTS

Rats raised in an enriched, stimulating environment had greater cortical depth in the brain (Diamond et al., 1966). Rats raised in a group of 12 in a complex environment, enriched with toys with which to play, had greater dendritic (nerve-fiber) branching in the visual part of the brain's cortex, compared to that in rats kept in pairs or individually in standard laboratory cages (Volkmar and Greenough, 1972).

The purpose of this phase of our study was to determine whether the changes observed in rats would also occur in pigs. This was taken as an initial step in developing an objective test to measure the relative stimulation level of different swine production systems.

The pigs were slaughtered at the end of the 9-week trial already described. Three different measurements were made on the pigs' brains. Brain weight and size were measured in 12 of the pigs (six from the simple environment, six from the complex), and cortical depth and dendritic branching were measured in the other twelve. Cortical depth and dendritic branching were measured in that part of the brain's somatosensory cortex that corresponds with the end of the snout. This area was chosen because the pig explores its environment mainly with its snout, and a large part of the pig's brain is devoted to receiving sensory input from the snout (Adrian, 1943).

There were no significant differences between pigs from the two environments for either weights or dimensions of the brain's cortex or cerebellum. The medulla was slightly heavier in complex-environment pigs than in those from the simple environment, but the difference was not statistically significant. Brain weights and dimensions were crude reflectors of any environmental differences perceived by the pigs.

The cortical-depth difference between the two groups approached statistical significance. These values varied greatly among animals, but there was a trend toward the pigs from the simple environment having a greater cortical thickness.

Microscopic analysis of dendritic branching is still in progress. A preliminary finding is that the pigs from the complex environment might have had less dendritic branching than had the pigs from the simple environment. This finding runs counter to what we originally expected. The original hypothesis was that the pigs from the complex environment would have thicker cortices and more dendritic branching than would those from the simple environment.

It might be that the pigs in the simple environment actually received more physical stimulation on the ends of their snouts than did the complex-environment pigs. Pigs in the simple environment repeatedly unscrewed bolts in the pen partitions, and sometimes they rubbed their noses on the floor and played with the nipple waterer. Maybe the pigs in the complex environment received less physical stimulation on the ends of their noses because they were receiving more varied stimulation through their other senses, which might have diverted some of their attention away from activities that strongly stimulate the snout. We did not make detailed behavioral observations in this experiment.

These results indicate that effects of environmental complexity on the central nervous system are complicated. Perhaps environmental complexity has different effects on different parts of the brain. Now we plan to study other parts of the brain, such as the visual cortex, in these same pigs.

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